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Naval Education and
Training Command

NAVEDTRA 12532
October 1990
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Training Manual
(TRAMAN)

Utilitiesman 3

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Although the words "he," "him," and "his" are used sparingly in this manual to enhance communication, they are not intended to be gender driven nor to affront or discriminate against anyone reading this text.

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Naval Education And Training Program Management Support Activity

UTILITIESMAN 3

NAVEDTRA 12532

DEPARTMENT OF THE NAVY
CHIEF OF NAVAL EDUC AND TNG

1990 Edition Prepared by
UTCS Junior D. Sims, USN

PREFACE

This rate training manual (TRAMAN), NAVEDTRA 12532, and its companion nonresident training course (NRTC), NAVEDTRA 82532, form a self-study package that will greatly aid Utilitiesmen in fulfilling the requirements of their rating. Among these requirements are the abilities to plan, estimate, schedule, and perform tasks involved in the installation, maintenance, and repair of plumbing, heating, steam, compressed-air, air conditioning, and refrigeration systems. This updated TRAMAN presents information on field water treatment equipment and processes and advanced base field support facilities.

Designed for individual study and not formal classroom instruction, this TRAMAN provides subject matter that relates directly to the occupational standards of the Utilitiesman rating. The NRTC provides a way of satisfying the requirements for completing the TRAMAN. The assignments in the NRTC include learning objectives and supporting items designed to lead the student through the TRAMAN.

This TRAMAN was prepared by the Naval Education and Training Program Management Support Activity, Pensacola, Florida, for the Chief of Naval Education and Training. Technical assistance was provided by the Naval Facilities Engineering Command, Alexandria, Virginia; the Naval Construction Training Center, the Naval Construction Battalion Center, and the Civil Engineering Support Office, Port Hueneme, California; the Naval Construction Training Center, the Naval Construction Battalion Center, and the 20th Naval Construction Regiment, Gulfport, Mississippi.

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THE UNITED STATES NAVY

GUARDIAN OF OUR COUNTRY

The United States Navy is responsible for maintaining control of the sea and is a ready force on watch at home and overseas, capable of strong action to preserve the peace or of instant offensive action to win in war.

It is upon the maintenance of this control that our country's glorious future depends; the United States Navy exists to make it so.

WE SERVE WITH HONOR

Tradition, valor, and victory are the Navy's heritage from the past. To these may be added dedication, discipline, and vigilance as the watchwords of the present and the future.

At home or on distant stations we serve with pride, confident in the respect of our country, our shipmates, and our families.

Our responsibilities sober us; our adversities strengthen us.

Service to God and Country is our special privilege. We serve with honor.

THE FUTURE OF THE NAVY

The Navy will always employ new weapons, new techniques, and greater power to protect and defend the United States on the sea, under the sea, and in the air.

Now and in the future, control of the sea gives the United States her greatest advantage for the maintenance of peace and for victory in war.

Mobility, surprise, dispersal, and offensive power are the keynotes of the new Navy. The roots of the Navy lie in a strong belief in the future, in continued dedication to our tasks, and in reflection on our heritage from the past.

Never have our opportunities and our responsibilities been greater.

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CREDITS

The illustrations listed below are included in this edition of *Utilitiesman 3* through the courtesy of the source designated. Permission to use these illustrations is gratefully acknowledged. Permission to reproduce illustrations and other materials in this publication must be obtained from the source.

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Ridge Tool Co.	3-62, 3-63 and 3-64

REGULATIONS ON ENVIRONMENTAL POLLUTION AND HAZARDOUS MATERIALS

Environmental Pollution and Hazardous Waste Handling and Disposal programs have been enacted and are United States law. These programs are of immense importance and should be taken into consideration during the planning stages before beginning any new construction or rehabilitation project.

As a member of the Naval Construction Forces, United States law requires you to be constantly aware of potential environmental pollution hazards or hazardous material spills and to report them to your immediate supervisor or other senior personnel at the earliest possible time.

The following list of directives contains information on the cognizant government departments and the procedures for preventing, reporting, and correcting environmental pollution hazards and hazardous materials disposal worldwide:

- Naval Occupational Safety and Health Program Manual, OPNAVINST 5100.23B
- Environmental and Natural Resources Protection Manual, OPNAVINST 5090.1
- Domestic Wastewater Control, MIL-HDBK 1005/8
- NAVFAC Pollution Control Manual, DM-5.8

CHAPTER 1

PLANS AND SPECIFICATIONS

Learning Objective: Recognize important aspects of plans and drawings; and identify the purpose of isometric sketches and specifications in construction operations.

In the day-to-day work as a Utilitiesman, you will be installing, assembling, inspecting, and troubleshooting refrigeration, air conditioning, and plumbing. To do these jobs properly, you must read and interpret plans and drawings. You may also have to read specifications that contain additional information on the details of construction and installation. Plans and specifications tie together to assist you in doing the job efficiently, correctly, and safely.

When studying this chapter, you should learn to read and interpret simple drawings and sketches and even the more complex installation plans by using the specifications to help you with details. In addition, you should be able to convert English system measurements to metric system equivalents. If you need to refresh your memory on the English and metric system relationships, refer to appendix II.

PLANS

You will be working with several types of plans and drawings, ranging from simple drawings and sketches, made perhaps by your immediate supervisor, to mechanical plans made by the draftsman using drawing instruments. The reproductions of the latter are the plans from which you will normally work.

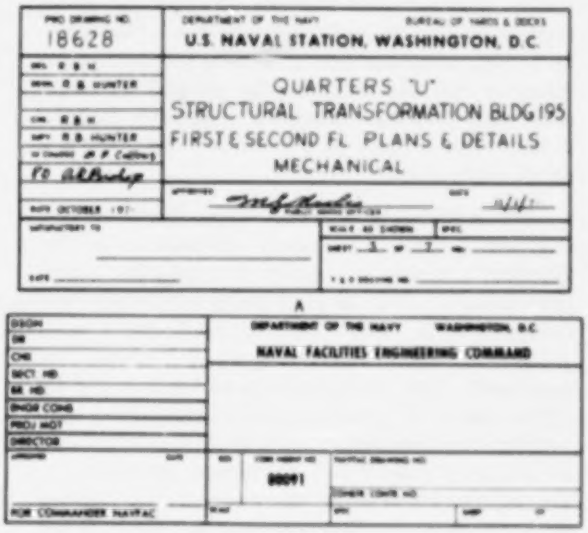
MECHANICAL PLANS

Mechanical plans include layouts and details for systems of plumbing, heating, ventilating, air conditioning, and refrigeration. These systems vary depending on whether they are for a permanent installation with the most modern fixtures and equipment or for a temporary installation where less complex equipment is used. Whatever the job, you should work directly from the plans so the finished job complies with the plans.

The chief parts of a mechanical plan are the views of the fixtures and equipment and the layout and details of the system. Plans also contain written information in the title block; the scales; the lines, symbols, and abbreviations; the notes; the revision block; the drawing, reference, and zone numbers; and the bill of material.

Title Block

The title block is in the lower right-hand corner of the drawing. A typical title block is shown in figure 1-1. The title block contains the


18628
U.S. NAVAL STATION, WASHINGTON, D.C.
R B HUNTER
R B HUNTER
QUARTERS "U"
STRUCTURAL TRANSFORMATION BLDG 195
FIRST & SECOND FL PLANS & DETAILS
MECHANICAL
OCTOBER
SCALE AS SHOWN
SHEET 1 OF 1
A
DESIGN
DR
CHK
SECT HD
BR HD
ENGR COORD
PROJ MGT
DIRECTOR
DEPARTMENT OF THE NAVY WASHINGTON, D.C.
NAVAL FACILITIES ENGINEERING COMMAND
80091
FOR COMMANDER NAVFAC
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45.159

Figure 1-1.—Title blocks.

title of the drawing and the number assigned to that drawing. It indicates the persons who prepared the drawing, checked it, and the authority under which it was issued. It also indicates the date approved, the scale, the specification numbers, and the sheet number of multiple-sheet drawings.

Scales

To help you visualize the size and shape of the system, the architect reduces all dimensions to scale. Thus, on a drawing where the architect represents a foot by 1/2 inch, a 40-foot run of pipe is 20 inches long.

The scale of a drawing is important to the construction workers; it also has a practical value to the Utilitiesman. Where piping is to be installed, the dimensions of the pipes and the distances between them have to be considered in figuring the amount of piping required and the number of fittings needed to join them.

Remember, NEVER MEASURE A DRAWING. USE THE DIMENSIONS. Why? Because the print may have been reduced from the original drawing; or you may not have considered the scale of the drawing. Also, paper stretches and shrinks as the humidity changes. Do not take a measurement by laying a rule on the print itself. Play it safe and READ the dimensions on the drawing; they always remain the same.

GRAPHICAL SCALES.—Graphical scales are often placed on maps and plot plans. These scales indicate the number of feet or miles represented by an inch. A fraction is often used, as 1/500, meaning that one unit on the map is equal to 500 like-units on the ground. A large-scale map may have a scale of 1 inch = 10 feet; a map with a scale of 1 inch = 1,000 feet is a small-scale map.

ENGINEER'S SCALE.—The chain, or civil engineer's scale, commonly referred to as the engineer's scale, is usually a triangular scale, containing six fully divided scales subdivided into decimals with each major interval on a scale subdivided into tenths. Figure 1-2 shows the engineer's scale and segments of each of the six scales. Each of the six scales is designated by a number representing the number of graduations a particular scale has to the linear inch. For example, on the 10 scale, there are 10 graduations to the inch; on the 50 scale, there are 50. You can see that the 50 scale has 50 graduations in the same space occupied by 10 graduations on the 10 scale. This space equates to 1 linear inch.

To determine the actual number of graduations represented by a numeral on the engineer's scale, multiply the numeral by 10. On the 50 scale, for instance, the numeral 2 indicates 2 by 10, or 20 graduations from the 0. On the 10 scale, the numeral 11 indicates 11 by 10, or 110 graduations from the 0. Note that the 10 scale is numbered every major graduation, while the 50 scale is numbered every other graduation. Other scales on the engineer's scale are the 20, 30, 40, and 60.

Because it is divided into decimals, the engineer's scale can scale dimensions down to any scale in which the first figure in the ratio is 1 inch and the other is 10, or a multiple of 10.

Suppose you want to scale a dimension of 150 miles down to a scale of 1/2 inch = 60 miles. Use the 60 scale and allow the interval between adjacent graduations to represent 1 mile. To measure off 150 miles to scale on the 60 scale, measure off 2.5 inches, which falls on the 15th major graduation.

Suppose you want to scale a dimension of 6,500 feet down to a scale of 1 inch = 1,000 feet. The second figure in the ratio is a multiple of 10 times a multiple of 10. Use the 10 scale and allow the interval between adjacent graduations on the scale to represent 100 feet. The interval between adjacent numerals on the scale indicates 1,000 feet. To measure 6,500 feet, simply measure off 6.5 inches on the scale.

To use the engineer's scale for scales expressed in fractions, you must be able to determine the fractional equivalent of each of the scales. For any scale, this equivalent is simply 1 over the total number of graduations on the scale, or 1 over the product of the scale number and 12. Under this rule, the fractional expression of each of the scales is as follows:

$$10 \text{ scale} = \frac{1}{120}$$

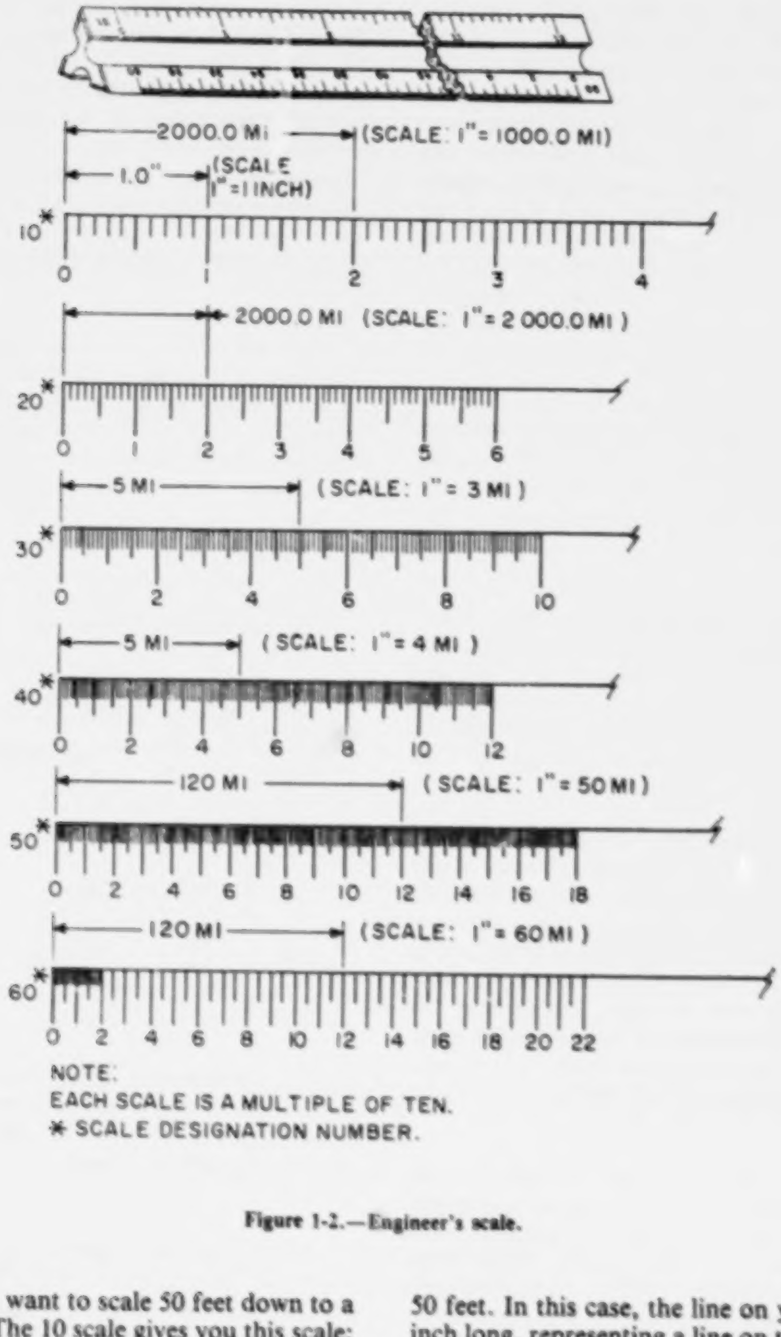
$$20 \text{ scale} = \frac{1}{240}$$

$$30 \text{ scale} = \frac{1}{360}$$

$$40 \text{ scale} = \frac{1}{480}$$

$$50 \text{ scale} = \frac{1}{600}$$

$$60 \text{ scale} = \frac{1}{720}$$


2000.0 MI
(SCALE: 1" = 1000.0 MI)
1.0"
(SCALE 1" = 1 INCH)
10*
0 1 2 3 4
2000.0 MI (SCALE: 1" = 2 000.0 MI)
20*
0 1 2 3 4 5 6
5 MI
(SCALE: 1" = 3 MI)
30*
0 2 4 6 8 10
5 MI
(SCALE: 1" = 4 MI)
40*
0 2 4 6 8 10 12
120 MI
(SCALE: 1" = 50 MI)
50*
0 2 4 6 8 10 12 14 16 18
120 MI
(SCALE: 1" = 60 MI)
60*
0 2 4 6 8 10 12 14 16 18 20 22

NOTE:
EACH SCALE IS A MULTIPLE OF TEN.
* SCALE DESIGNATION NUMBER.

142.321

Figure 1-2.—Engineer's scale.

Suppose you want to scale 50 feet down to a scale of 1/120. The 10 scale gives you this scale; you would use the 10 scale, allowing the space between graduations to represent 1 foot, and measure off 5 (for 50 feet). The line on your paper is 5 inches long, representing a line on the object itself that is 120 by 5 inches, or 600 inches (50 feet) long.

If you want to scale 50 feet down to a scale of 1/600, use the 50 scale and measure off 5 for 50 feet. In this case, the line on your paper is 1 inch long, representing a line on the object itself that is 1 by 600, or 600 inches (50 feet) long.

When the drawing is not made to a specified scale—that is, when the dimensions of lines on the drawing are not required to bear a specified ratio to the dimensions of lines on the object itself—the most convenient scale on the engineer's scale is used. Suppose you want to draw the outline of a 360- by 800-foot rectangular field on an 8- by 10 1/2-inch sheet of paper with no specific scale prescribed. Simply reduce the representation of the object to one that fits the dimensions of the paper. You could use the 10 scale and allow the interval between adjacent graduations to represent 10 feet. In this case, the numerals on the scale, instead of representing 10, 20, and so on, represents 100, 200, and so on. To measure off 360 feet to scale, measure from 0 to the 6th graduation beyond the numeral 3. For 800 feet, measure from 0 to the numeral 8.

Because you allowed the interval between adjacent graduations to represent 10 feet and because the 10 scale has 10 graduations to the inch, the scale of your drawing is 1 inch = 100 feet, or 1/1200.

ARCHITECT'S SCALE.—Architect's scales are usually triangular in shape and are used wherever dimensions are measured in feet and inches. Major divisions on the scale represent feet which, in turn, are subdivided into 12ths or 16ths, depending on what individual scale is being used.

Figure 1-3 shows the triangular architect's scale. Also shown are segments of each of the eleven scales found on this particular type of scale. Notice that all scales except the 16th scale are actually two scales that read from either left to right or right to left. When reading a scale numbered from left to right, notice that the numerals are located closest to the outside edge. On scales that are numbered from right to left, notice that the numerals are located closer to the inside edge.

Architect's scales are "open" divided (only the main divisions are marked throughout the length) with the only subdivided interval being an extra interval below the 0-foot mark. These extra intervals are divided into 12ths. To make a scale measurement in feet and inches, you measure off the number of feet on the main scale and add the inches on the subdivided extra interval. However, notice that the 16th scale is fully divided with its divisions being divided into 16ths.

Now let's measure off a distance of 1 foot 3 inches to see how each scale is read and how the scales compare to one another. (Refer to fig. 1-3.) Since the graduations on the 16 scale are subdivided into 16ths, 3 inches actually is 3/12 or 1/4 of a foot. Changing this to 16ths, measure off 4/16ths to equal the 3-inch measurement. Note carefully the value of the graduations on the extra interval, which varies with different scales. On the 3 inches = 1 foot scale, for example, the space between adjacent graduations represents 1/8 inch. On the 3/32 inch = 1 foot scale, each space between adjacent graduations represents 2 inches.

The scale 3/32 = 1 foot, expressed fractionally, comes to 3/32 = 12 inches, or 1/128. This is the smallest scale provided on an architect's scale. The scales on the architect's scale, with their fractional equivalents, are as follows:

3 inches = 1 foot .... $\frac{1}{4}$ scale

$1\frac{1}{2}$ inches = 1 foot .... $\frac{1}{8}$ scale

1 inch = 1 foot .... $\frac{1}{12}$ scale

$\frac{3}{4}$ inch = 1 foot .... $\frac{1}{16}$ scale

$\frac{1}{2}$ inch = 1 foot .... $\frac{1}{24}$ scale

$\frac{3}{8}$ inch = 1 foot .... $\frac{1}{32}$ scale

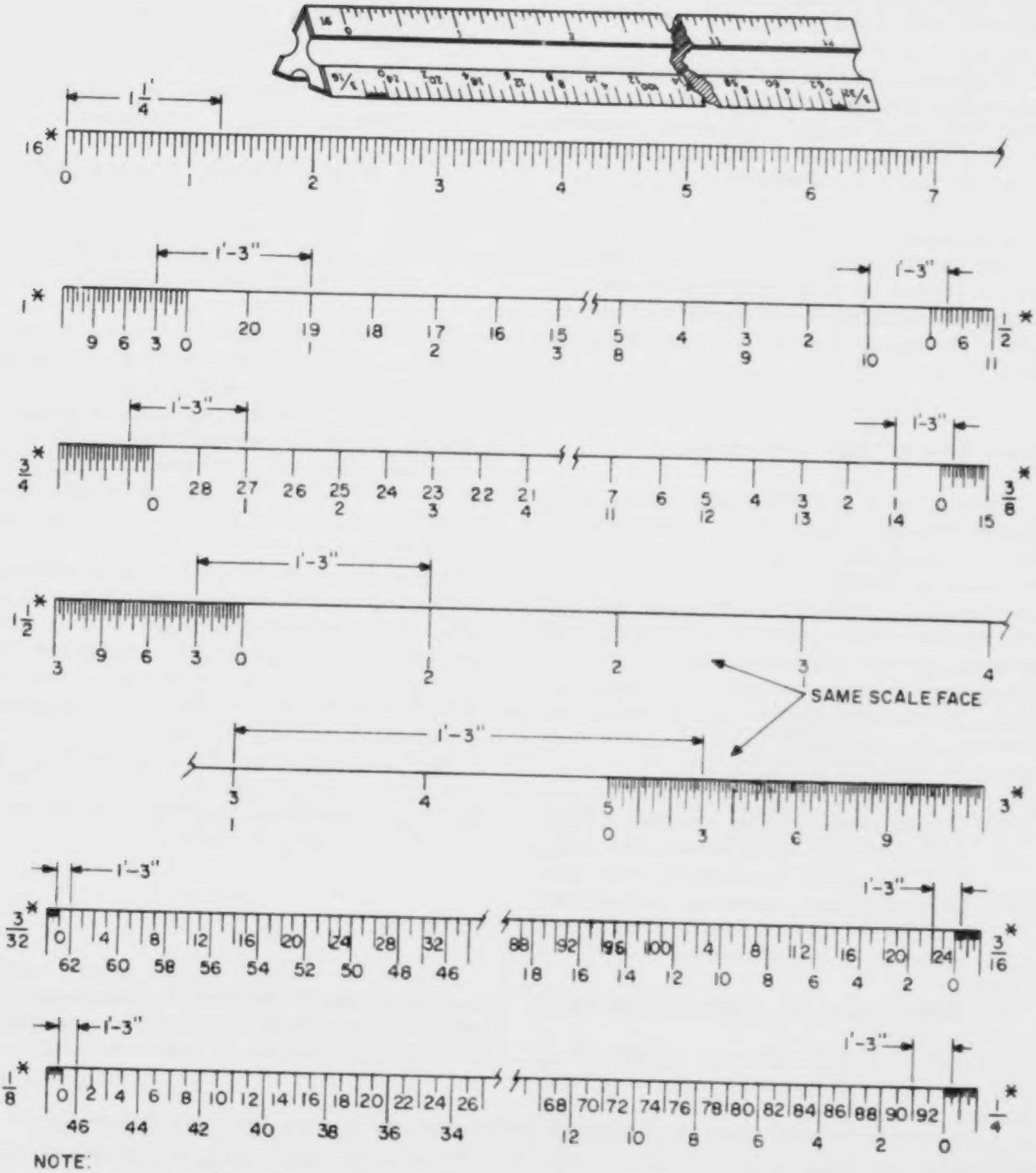
$\frac{1}{4}$ inch = 1 foot .... $\frac{1}{48}$ scale

$\frac{3}{16}$ inch = 1 foot .... $\frac{1}{64}$ scale

$\frac{1}{8}$ inch = 1 foot .... $\frac{1}{96}$ scale

$\frac{3}{32}$ inch = 1 foot .... $\frac{1}{128}$ scale

METRIC SCALE.—When measurements and dimensions are in meters and centimeters, the metric scale is used in the place of the architect's and the engineer's scales. Metric scales are available in flat and triangular shapes. The flat


1 1/4'
16*
0 1 2 3 4 5 6 7
1'-3"
1*
9 6 3 0 20 19 18 17 16 15 5 4 3 2 10 0 6
1 2 3 8 9 11
1/2*
3/4*
0 28 27 26 25 24 23 22 21 7 6 5 4 3 2 1 0
1 2 3 4 11 12 13 14 15
3/8*
1 1/2*
3 9 6 3 0 1 2 3 4
2
SAME SCALE FACE
3 4 5
1 0 3 6 9
3*
3/32*
0 4 8 12 16 20 24 28 32 88 92 96 100 4 8 12 16 20 24
62 60 58 56 54 52 50 48 46 18 16 14 12 10 8 6 4 2 0
3/16*
1/8*
0 2 4 6 8 10 12 14 16 18 20 22 24 26 68 70 72 74 76 78 80 82 84 86 88 90 92
46 44 42 40 38 36 34 12 10 8 6 4 2 0
1/4*

NOTE:
16 SCALE IS SUBDIVIDED INTO SIXTEENTHS.
ALL OTHERS ARE SUBDIVIDED INTO TWELFTHS.
* SCALE DESIGNATION NUMBERS.

142.320

Figure 1-3.—Architect's scale.

30-cm metric scale is shown in figure 1-4. The top scale is calibrated in millimeters and the bottom scale in half-millimeters. The triangular metric scale has six fully divided scales which are 1:20, 1:33 1/3, 1:40, 1:50, 1:80, and 1:100.

When using scales on a drawing, you should not confuse the engineer's scale with the metric scale. They look a lot alike. Whenever conversions are made between the metric and English systems, remember that 2.54 centimeters equal 1 inch.

A thorough knowledge of the metric system is important. If you are NOT completely familiar with the subject, go to appendix II and review the system. For more detailed information on metrics, refer to the manual *The Metric System,* NAVEDTRA 475-01-00-79.

Lines, Symbols, and Abbreviations

Lines, symbols, and abbreviations are used to prepare drawings, and each has a special meaning. To ensure that all the lines, symbols, and abbreviations used by the armed forces have the same meaning to each person, lines, symbols, and abbreviations have been standardized and approved by the Department of Defense. To ensure uniformity, clearness, conciseness, legibility, and readability by anyone using the drawings or blueprints, use the following references from NAVFAC DM-6:

(1) Conventions—For line, lettering, section, and sectioning conventions, see MIL-STD-100 (latest revision), in order that building sections, elevations, wall sections, and details may be readily located and identified on the drawings.

(2) Abbreviations—Use MIL-STD-12 (latest revision).

(3) Civil Symbols—Symbols are contained in Abbet, *American Civil Engineering Practice,* Volume 1.

(4) Architectural Symbols—Use MIL-STD-14 (latest revision).

(5) Structural Symbols—Use MIL-STD-18 (latest revision).

(6) Mechanical Symbols—Use MIL-STD-17 (latest revision).

(7) Electrical and Electronic Symbols, see ANSI Y14, 15 (latest revision).

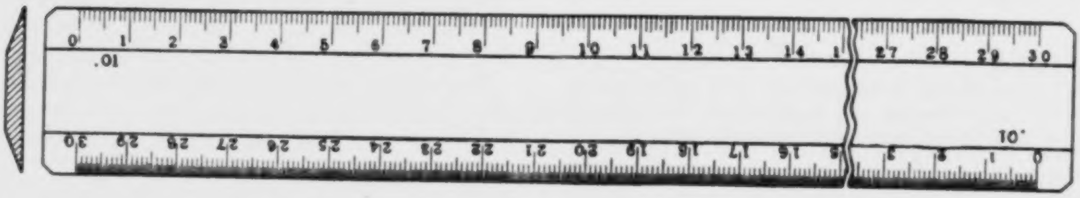
To do your job properly, you must interpret current and older symbols in new construction and on repair work. On a new job, you will probably use new plans with the latest approved lines, symbols, and abbreviations. When attached to a public works shop on a base that is 10 to 20 years old, you will have to refer to plans with lines, symbols, and abbreviations in use during that period of time.

Figure 1-5 shows a few of the more common mechanical symbols extracted from MIL-STD-17B-1. Figures 1-6 through 1-11 show some mechanical symbols used by the Utilitiesman. The older symbols are generally similar; if you can identify the new ones, you should NOT have any trouble understanding the older ones.

We have talked briefly about reading and interpreting plans. Chapters 1, 2, 7, 8, and 10 of *Blueprint Reading and Sketching,* NAVEDTRA 10077-F1, will help you more.

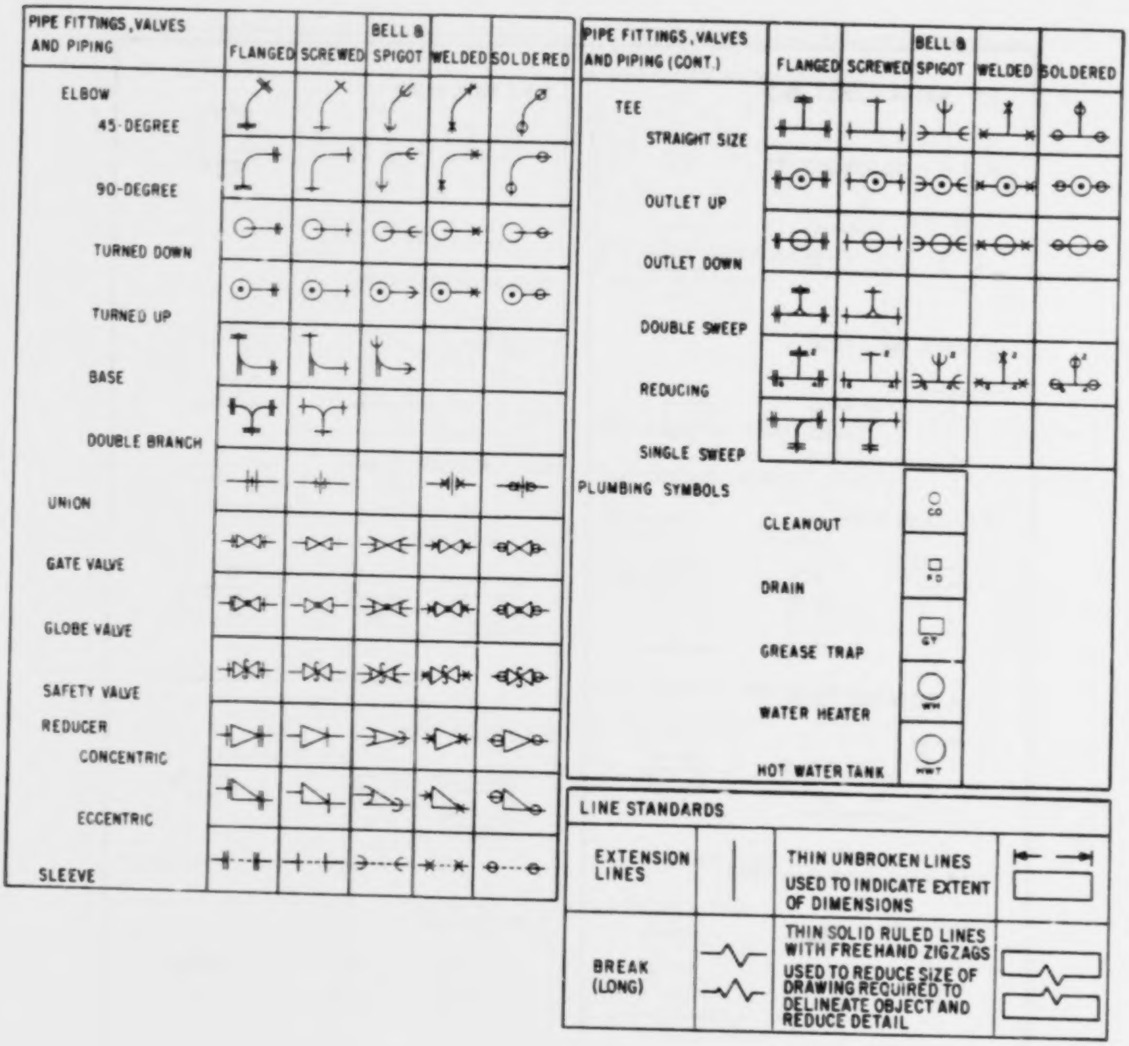
Notes

Notes are written to be clear, explicit statements about material, construction, and finish. Notes contain procedures for installation



4.16A

Figure 1-4.—Flat metric scale.


PIPE FITTINGS, VALVES AND PIPING
FLANGED
SCREWED
BELL & SPIGOT
WELDED
SOLDERED
ELBOW
45-DEGREE
90-DEGREE
TURNED DOWN
TURNED UP
BASE
DOUBLE BRANCH
UNION
GATE VALVE
GLOBE VALVE
SAFETY VALVE
REDUCER
CONCENTRIC
ECCENTRIC
SLEEVE
PIPE FITTINGS, VALVES AND PIPING (CONT.)
TEE
STRAIGHT SIZE
OUTLET UP
OUTLET DOWN
DOUBLE SWEEP
REDUCING
SINGLE SWEEP
PLUMBING SYMBOLS
CLEANOUT
CO
DRAIN
FD
GREASE TRAP
GT
WATER HEATER
WH
HOT WATER TANK
HWT
LINE STANDARDS
EXTENSION LINES
THIN UNBROKEN LINES
USED TO INDICATE EXTENT OF DIMENSIONS
BREAK (LONG)
THIN SOLID RULED LINES WITH FREEHAND ZIGZAGS
USED TO REDUCE SIZE OF DRAWING REQUIRED TO DELINEATE OBJECT AND REDUCE DETAIL

11.330

Figure 1-5.—Mechanical symbols.

and may contain explanations of specific parts of a drawing and other information not in the drawing. Always read the notes before beginning construction.

Revision Block

The revision block is usually directly above the title block, as shown in figure 1-12. This block is used to record changes (revisions) to the blueprint. All revisions are noted in this section and are dated and approved by cognizant authority.

Drawing Numbers

Blueprints are identified by a NAVFAC drawing number, as shown in the bottom right-hand corner of figure 1-12. Blueprints may also be identified in other places; for example, near the top border line in the upper corner, or on the reverse side at both ends. This allows you to see the number when the drawing is rolled up. A blueprint with more than one sheet will be shown in the number block as a specific sheet number within a number of sheets in a series. For example, in the title block shown in figure 1-12, that particular sheet is sheet 1 of 2.

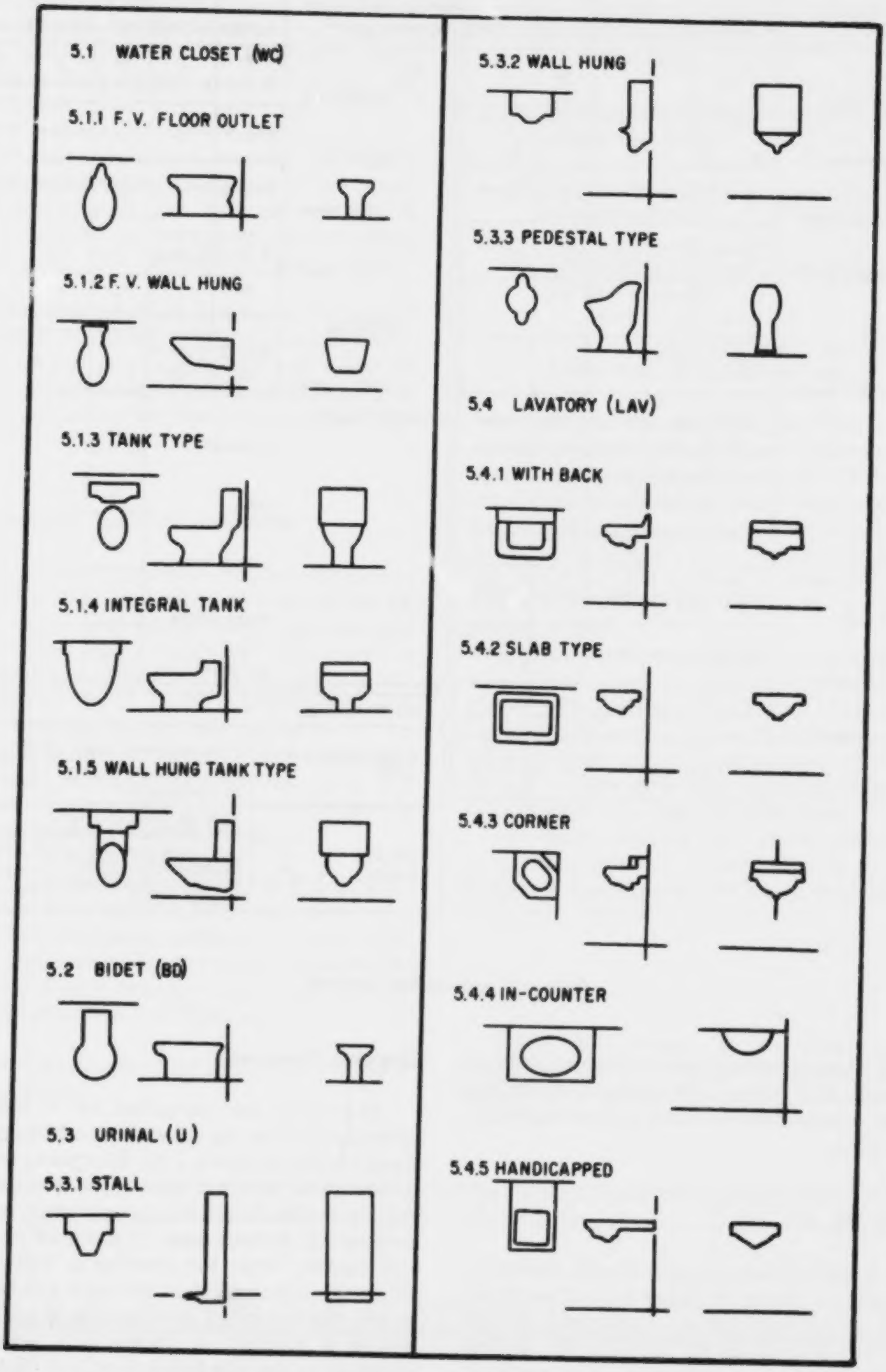

5.1 WATER CLOSET (WC)
5.1.1 F. V. FLOOR OUTLET
5.1.2 F. V. WALL HUNG
5.1.3 TANK TYPE
5.1.4 INTEGRAL TANK
5.1.5 WALL HUNG TANK TYPE
5.2 BIDET (BD)
5.3 URINAL (U)
5.3.1 STALL
5.3.2 WALL HUNG
5.3.3 PEDESTAL TYPE
5.4 LAVATORY (LAV)
5.4.1 WITH BACK
5.4.2 SLAB TYPE
5.4.3 CORNER
5.4.4 IN-COUNTER
5.4.5 HANDICAPPED

Figure 1-6.—Water closet and lavatory fixture symbols.

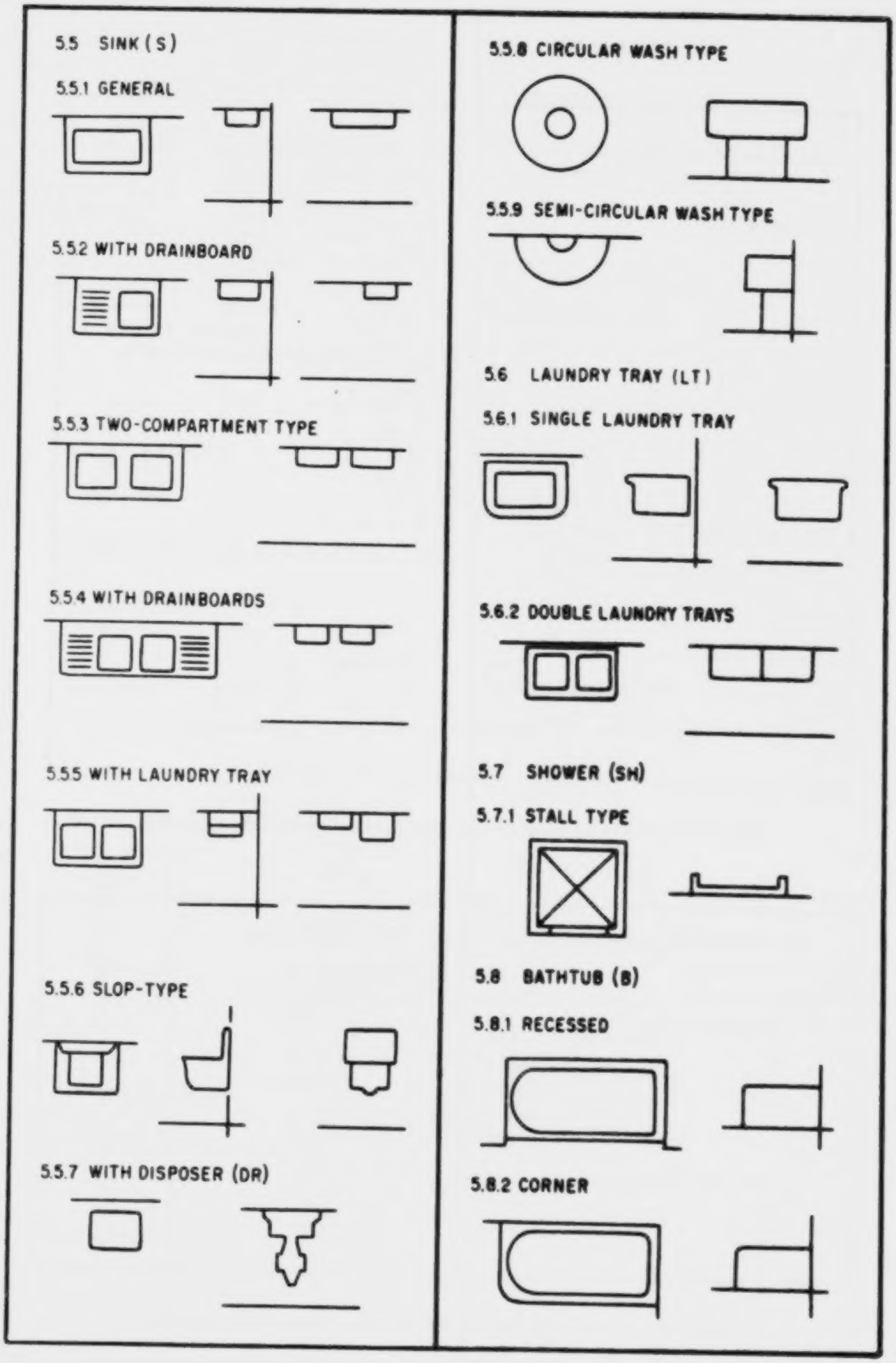

5.5 SINK (S)
5.5.1 GENERAL
5.5.2 WITH DRAINBOARD
5.5.3 TWO-COMPARTMENT TYPE
5.5.4 WITH DRAINBOARDS
5.5.5 WITH LAUNDRY TRAY
5.5.6 SLOP-TYPE
5.5.7 WITH DISPOSER (DR)
5.5.8 CIRCULAR WASH TYPE
5.5.9 SEMI-CIRCULAR WASH TYPE
5.6 LAUNDRY TRAY (LT)
5.6.1 SINGLE LAUNDRY TRAY
5.6.2 DOUBLE LAUNDRY TRAYS
5.7 SHOWER (SH)
5.7.1 STALL TYPE
5.8 BATHTUB (B)
5.8.1 RECESSED
5.8.2 CORNER

Figure 1-7.—Sink, laundry tray, shower, and bathtub fixture symbols.

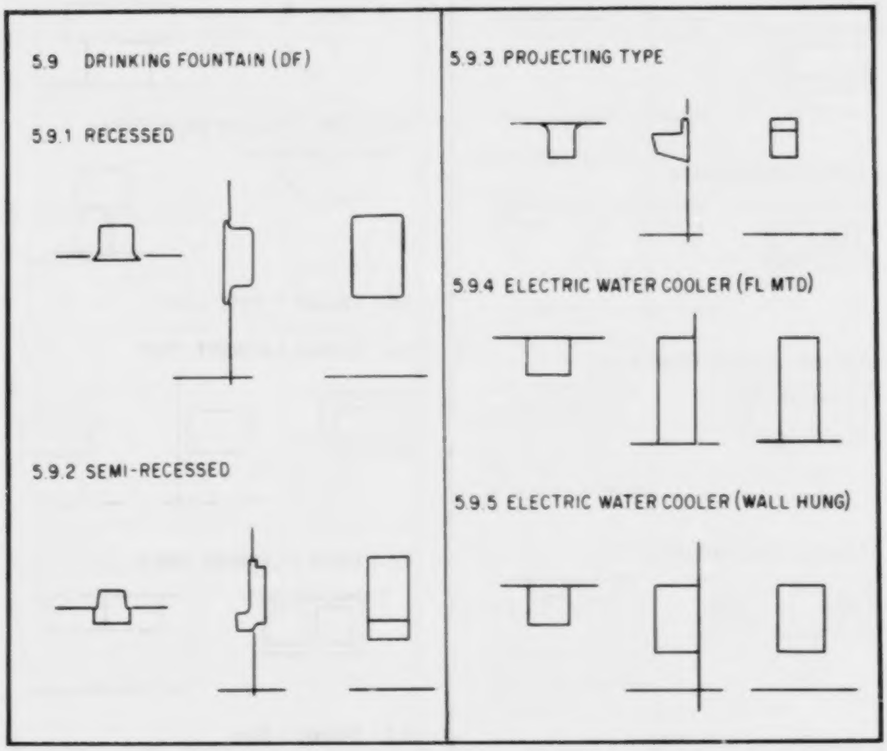

5.9 DRINKING FOUNTAIN (DF)
5.9.1 RECESSED
5.9.2 SEMI-RECESSED
5.9.3 PROJECTING TYPE
5.9.4 ELECTRIC WATER COOLER (FL MTD)
5.9.5 ELECTRIC WATER COOLER (WALL HUNG)

Figure 1-8.—Drinking fountain and electric water cooler fixture symbols.

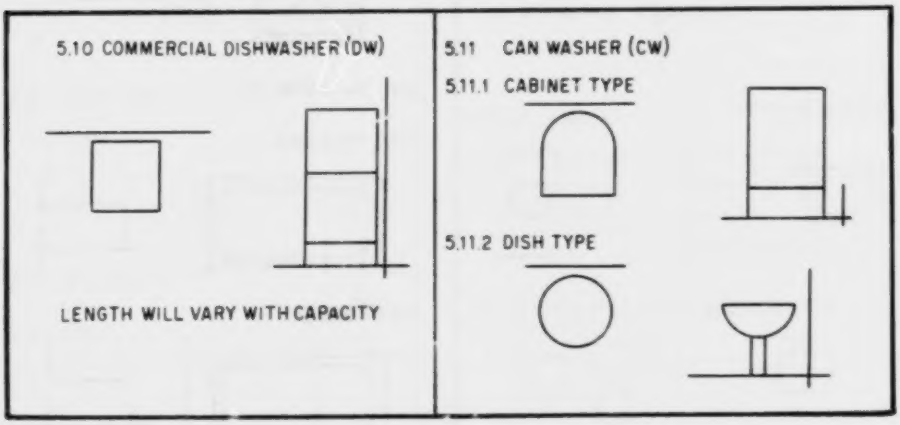

5.10 COMMERCIAL DISHWASHER (DW)
LENGTH WILL VARY WITH CAPACITY
5.11 CAN WASHER (CW)
5.11.1 CABINET TYPE
5.11.2 DISH TYPE

Figure 1-9.—Commercial dishwasher and can washer fixture symbols.

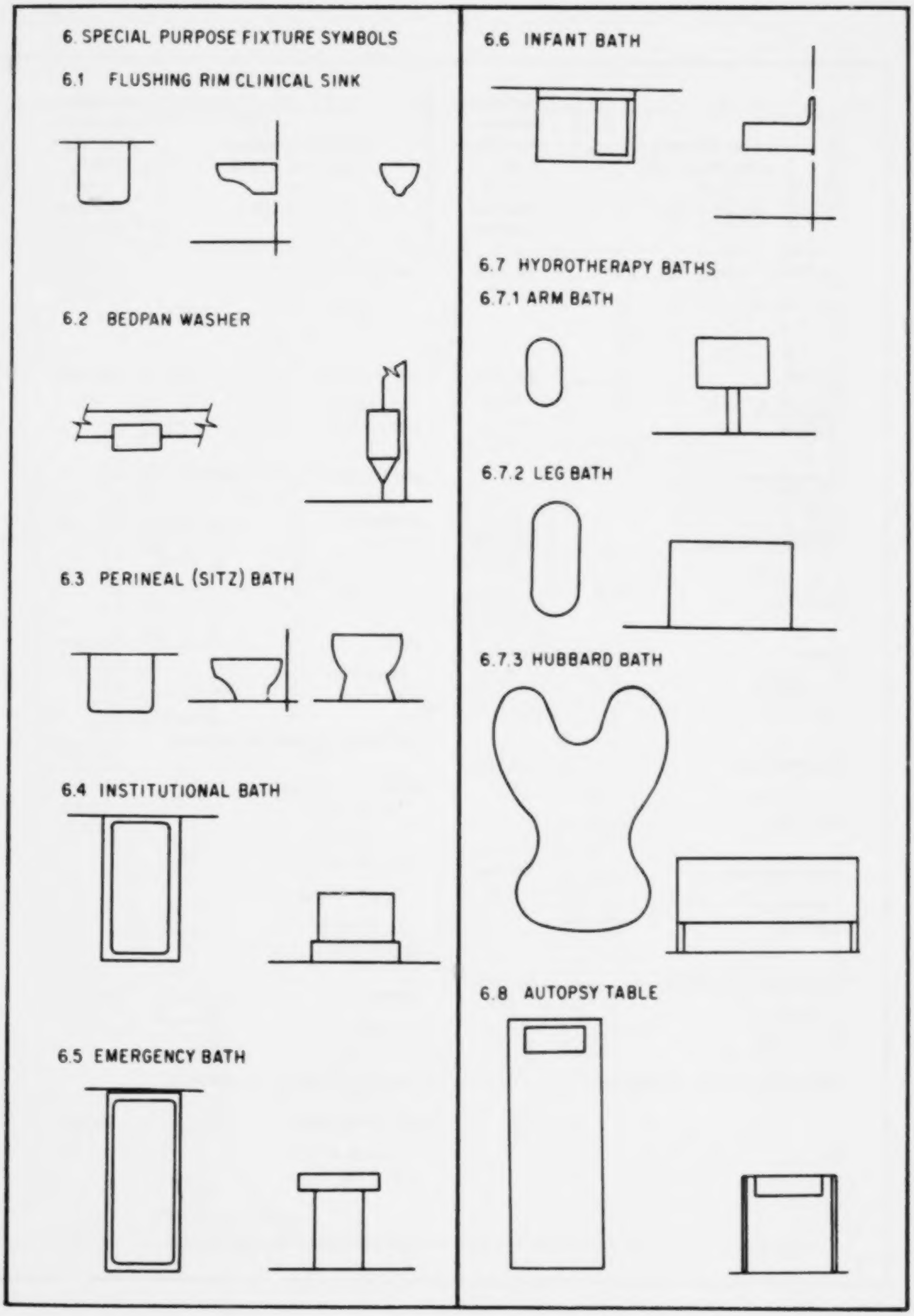
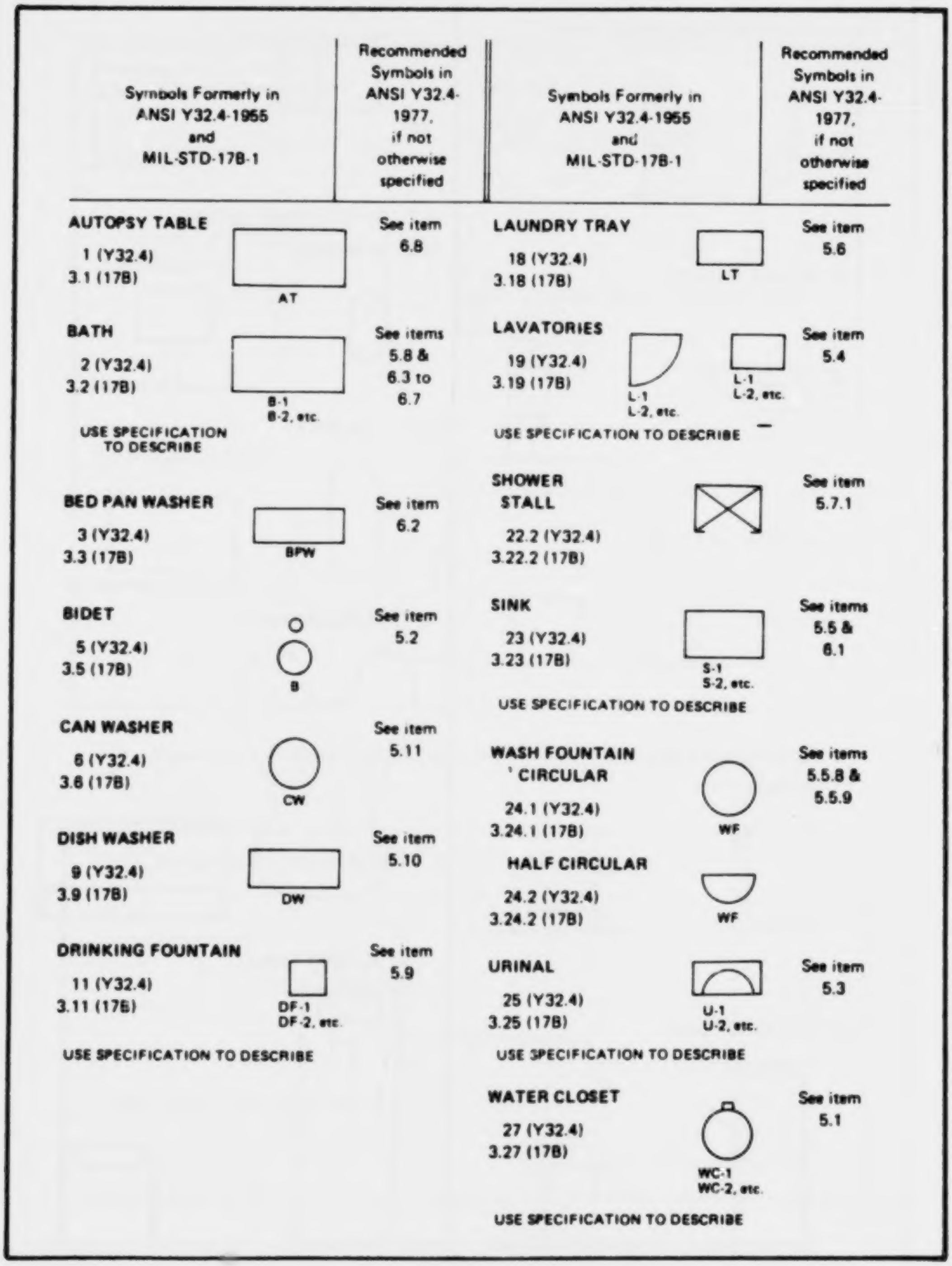

6. SPECIAL PURPOSE FIXTURE SYMBOLS
6.1 FLUSHING RIM CLINICAL SINK
6.2 BEDPAN WASHER
6.3 PERINEAL (SITZ) BATH
6.4 INSTITUTIONAL BATH
6.5 EMERGENCY BATH
6.6 INFANT BATH
6.7 HYDROTHERAPY BATHS
6.7.1 ARM BATH
6.7.2 LEG BATH
6.7.3 HUBBARD BATH
6.8 AUTOPSY TABLE

Figure 1-10.—Special-purpose fixture symbols.



Symbols Formerly in ANSI Y32.4-1955 and MIL-STD-17B-1		Recommended Symbols in ANSI Y32.4-1977, if not otherwise specified
AUTOPSY TABLE 1 (Y32.4) 3.1 (17B)	AT	See item 6.8
BATH 2 (Y32.4) 3.2 (17B) USE SPECIFICATION TO DESCRIBE	B-1 B-2, etc.	See items 5.8 & 6.3 to 6.7
BED PAN WASHER 3 (Y32.4) 3.3 (17B)	BPW	See item 6.2
BIDET 5 (Y32.4) 3.5 (17B)	B	See item 5.2
CAN WASHER 6 (Y32.4) 3.6 (17B)	CW	See item 5.11
DISH WASHER 9 (Y32.4) 3.9 (17B)	DW	See item 5.10
DRINKING FOUNTAIN 11 (Y32.4) 3.11 (17B) USE SPECIFICATION TO DESCRIBE	DF-1 DF-2, etc.	See item 5.9

Symbols Formerly in ANSI Y32.4-1955 and MIL-STD-17B-1		Recommended Symbols in ANSI Y32.4-1977, if not otherwise specified
LAUNDRY TRAY 18 (Y32.4) 3.18 (17B)	LT	See item 5.6
LAVATORIES 19 (Y32.4) 3.19 (17B) USE SPECIFICATION TO DESCRIBE	L-1 L-2, etc. L-1 L-2, etc.	See item 5.4
SHOWER STALL 22.2 (Y32.4) 3.22.2 (17B)		See item 5.7.1
SINK 23 (Y32.4) 3.23 (17B) USE SPECIFICATION TO DESCRIBE	S-1 S-2, etc.	See items 5.5 & 6.1
WASH FOUNTAIN CIRCULAR 24.1 (Y32.4) 3.24.1 (17B)	WF	See items 5.5.8 & 5.5.9
HALF CIRCULAR 24.2 (Y32.4) 3.24.2 (17B)	WF	
URINAL 25 (Y32.4) 3.25 (17B) USE SPECIFICATION TO DESCRIBE	U-1 U-2, etc.	See item 5.3
WATER CLOSET 27 (Y32.4) 3.27 (17B) USE SPECIFICATION TO DESCRIBE	WC-1 WC-2, etc.	See item 5.1

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Figure 1-11.—Revised and deleted fixture symbols.

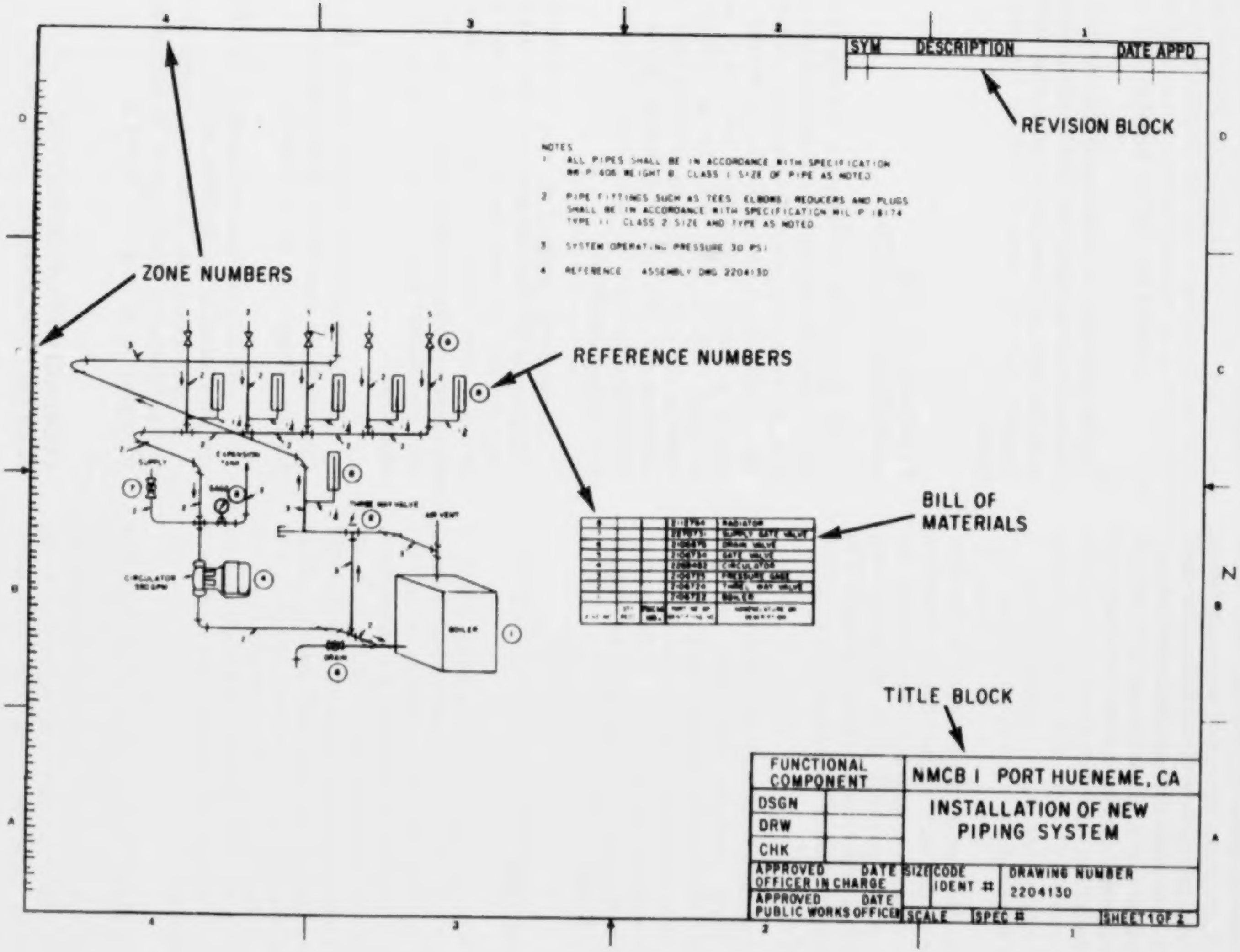
SYM
DESCRIPTION
DATE APPD
REVISION BLOCK
ZONE NUMBERS
NOTES
1 ALL PIPES SHALL BE IN ACCORDANCE WITH SPECIFICATION WW P 406 WEIGHT B CLASS 1 SIZE OF PIPE AS NOTED
2 PIPE FITTINGS SUCH AS TEES ELBOWS REDUCERS AND PLUGS SHALL BE IN ACCORDANCE WITH SPECIFICATION MIL P 18174 TYPE II CLASS 2 SIZE AND TYPE AS NOTED
3 SYSTEM OPERATING PRESSURE 30 PSI
4 REFERENCE ASSEMBLY DWG 2204130
REFERENCE NUMBERS
SUPPLY
EXPANSION TANK
THREE WAY VALVE
AIR VENT
CIRCULATOR
BOILER
DRAIN
RADIATOR
SUPPLY GATE VALVE
DRAIN VALVE
GATE VALVE
CIRCULATOR
PRESSURE GAGE
THREE WAY VALVE
BOILER
BILL OF MATERIALS
TITLE BLOCK
FUNCTIONAL COMPONENT
NMCB I PORT HUENEME, CA
DSGN
DRW
CHK
INSTALLATION OF NEW PIPING SYSTEM
APPROVED OFFICER IN CHARGE DATE
APPROVED PUBLIC WORKS OFFICER DATE
SIZE
CODE IDENT #
DRAWING NUMBER 2204130
SCALE
SPEC #
SHEET 1 OF 2
A
B
C
D
1
2
3
4
N

Figure 1-12.—Blueprint.

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Reference Numbers

Reference numbers (as shown in figure 1-12) appear near the parts they identify, both at the piping diagram and the bill of materials. Some commercial prints show the drawing and dash numbers, then point with a leader line to the part; other prints use a circle (about 3/8 inch in diameter) around the dash number, and then point with a leader line to the part.

Zone Numbers

Zone numbers on blueprints serve the same purpose as the numbers and letters printed on borders of maps to help you locate a point. To find a point, mentally draw horizontal and vertical lines from these letters and numerals. The point you are seeking is the point where the lines intersect.

You can use practically the same system to locate parts, sections, and views on large blueprints; for example, assembly drawings of aircraft. Parts numbered in the title block can be located on the drawing by looking up the numbers in squares along the lower border. Zone numbers read from right to left.

Bill of Material

A bill of material (sometimes called a material takeoff) is a grouped compilation based on takeoffs and estimates of all the materials required to complete the installation. The bill of material for a project is organized into a tabulated statement to include the item number of the parts and materials, their descriptions, the unit of measure, quantity, and stock number. A typical bill of material (fig. 1-12) shows that the item numbers in the first column refer to each item, its location, and its purpose or function.

In a Naval Mobile Construction Battalion (NMCB), a bill of material is prepared for a complete job, or project, and is referred to as the BM. This BM is prepared and maintained by the operations department and lists items under categories such as "used," "on hand," and so forth. Check the BM from time to time during a job to make sure the materials needed are actually available.

When equipment assemblies are received at an overseas base, you can quickly determine whether they meet job requirements by checking the bill of material.

ISOMETRIC SKETCHING

You may not be able to sketch or draw objects exactly as they should look. However, with the aid of some basic rules and daily practice, you can learn to draw an isometric sketch.

PURPOSE OF THE ISOMETRIC DRAWING

The purpose of an isometric drawing is to show a three-dimensional picture in one drawing. It resembles a picture without the artistic details. Many Utilitiesmen have difficulty in visualizing clearly a piping installation when they are working from a floor plan to an elevation drawing and back again. The isometric drawing combines the plan and the elevation. It clearly shows the details and the relationship of the pipes in a piping installation.

The isometric system of drawing is used by the Utililtiesman for two reasons: (1) it is easy to draw once the ideas are mastered and (2) the lines are drawn to scale length. It is possible to "scale" or measure lengths from an isometric drawing in the same manner that the architect's plan can be measured.

The isometric drawing follows certain rules or conventions to show three dimensions on a flat surface. These rules are as follows:

1. Vertical lines in an orthographic elevation remain vertical in an isometric sketch.
2. Horizontal lines in an orthographic elevation are projected at an angle of 30 degrees and 60 degrees in an isometric drawing.

COMPARISON OF ISOMETRIC AND ORTHOGRAPHIC DRAWINGS

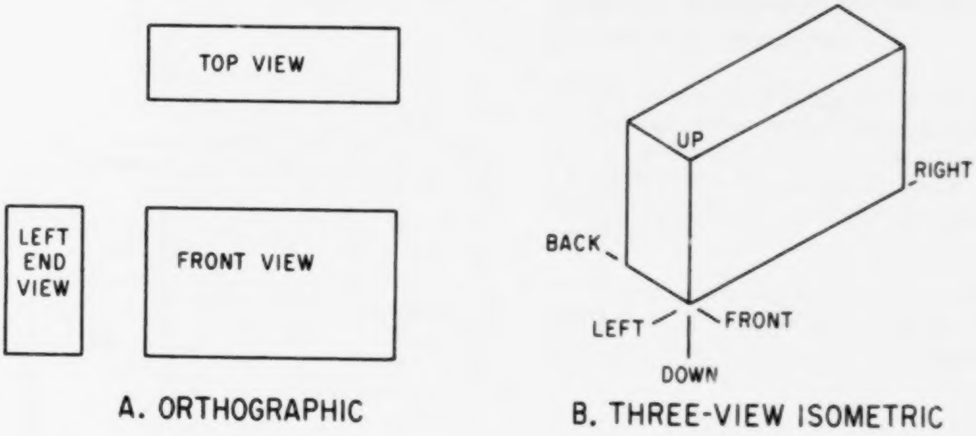
Compare the simple rectangular block shown in the orthographic representation in view A, figure 1-13, and the three-view isometric representation in view B. Notice that (1) the vertical lines of the orthographic drawing remain vertical in the isometric, (2) the horizontal lines of the orthographic drawing are NOT horizontal in the isometric but are projected at 30-degree and 60-degree angles, and (3) the lengths of the lines remain the same in the isometric as they were in the orthographic.

Once you understand the drawing in this block, the same idea can be applied to the drawing of the shape of a room, as shown in figure 1-14.

AIDS IN DRAWING ISOMETRIC PIPE DIAGRAMS

To determine the pipe layout, you can draw the dimensions of a room in several ways. Some Engineering Aid's suggest that the lines of the room be drawn with fine light lines, and the pipe diagram with heavy dark lines to give the effect of a transparent room you can see into, as shown in figure 1-15. This method requires drafting room equipment and is difficult in field sketching.

Another means of visualizing the pipe layout is to "section" or remove from the drawing those



A. ORTHOGRAPHIC

B. THREE-VIEW ISOMETRIC

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Figure 1-13.—Comparison of orthographic and isometric drawings.

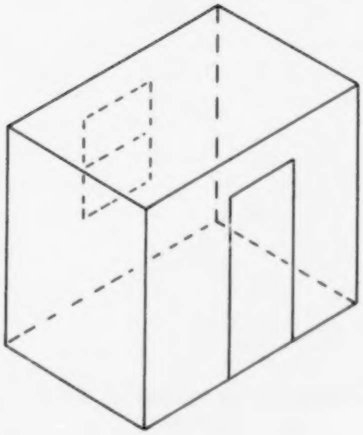


Figure 1-14.—Drawing of a room.

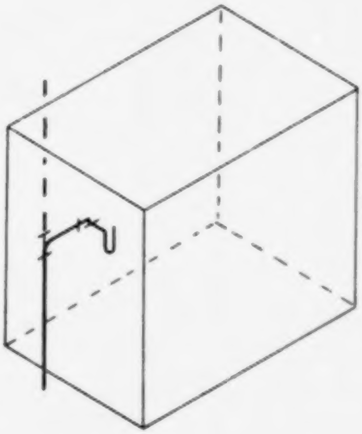


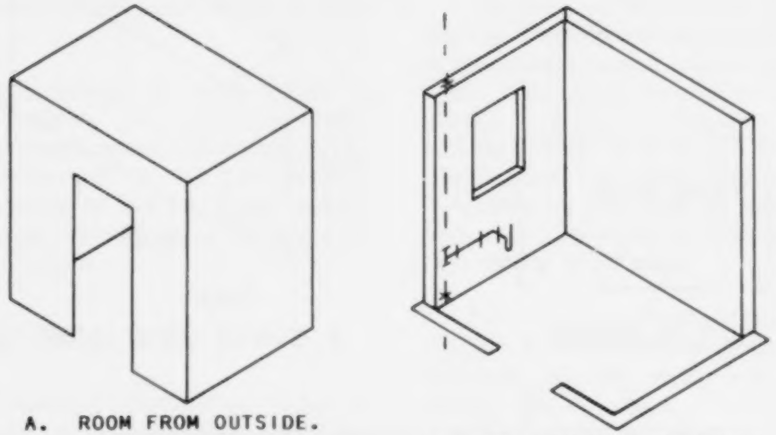
Figure 1-15.—Lightweight room lines.

parts in front of what is important to show. The usual section in a plumbing pipe layout leaves the ceiling and two walls out of the drawing, as shown in views A, B, and C of figure 1-16.

A third method is simpler in that the room is shown only as a partial floor plan view, as shown in view D, figure 1-16. The walls are omitted from the drawing entirely. It is understood that the walls are to be there, but they are left out so the piping diagram shows without unnecessary details.

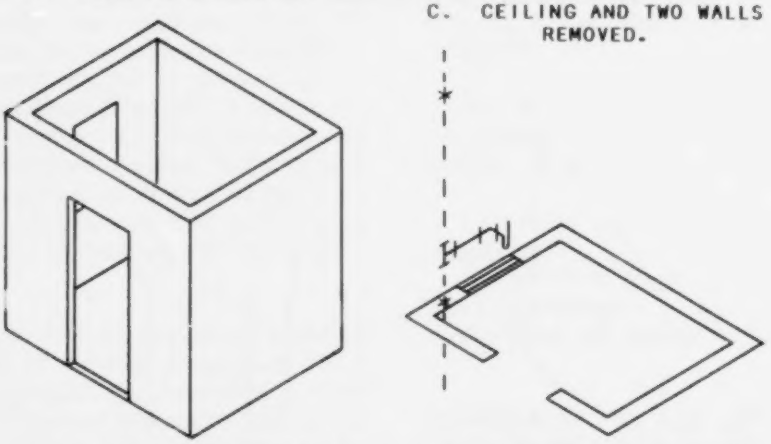
To lay out a 45-degree angle in an isometric drawing, draw a square and lay out the 45-degree angle, as shown in view A, figure 1-17. Now look at view B and you will see a block with a 45-degree chamfer. The chamfer is located by measuring equal distances from the corner that would ordinarily be there.

A piping diagram with a 45-degree angle, as shown in view C, would be very similar to the lines for part of the block, as shown in view B. To draw a 45-degree angle in an isometric drawing, begin with a 90-degree angle. Measure an equal distance from the intersection of the two legs connecting these points; then, establish two sides of a square. By connecting these points, you have established the diagonal, which is a 45-degree angle. In view C, point A would be the intersection of the two legs of a 90-degree angle, measured an equal distance along each leg; three fourths of an inch is used here. Now, locate points B and C. Connect points B and C, and you have established the 45-degree offset.



A. ROOM FROM OUTSIDE.

C. CEILING AND TWO WALLS REMOVED.



B. ROOM WITH CEILING REMOVED.

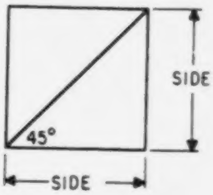
D. SCHEMATIC SECTION.

Figure 1-16.—Isometric sectioning in a plumbing pipe layout.

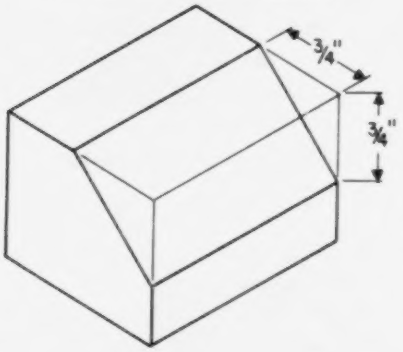
Some isometric practices are listed below to further develop your sketching skills.

1. Make an isometric drawing of a brick 8 by 3 3/4 by 2 1/4 inches. Make each line full size, but do NOT dimension the drawing.

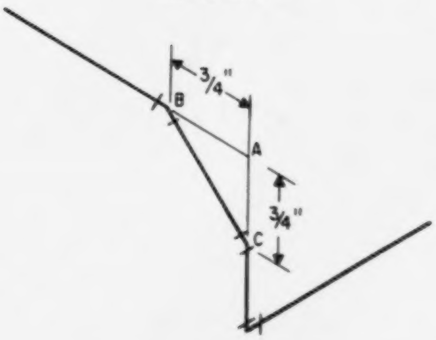
2. A bathroom is 5 feet wide, 8 feet long, and 7 feet 6 inches high. Make an isometric drawing of this shape to a scale of 1/2 inch = 1 foot.



A. A 45-DEGREE LINE BY DIAGONAL IN A SQUARE.



B. BLOCK WITH 45-DEGREE CHAMFER.



C. PIPE DIAGRAM WITH 45-DEGREE DIAGONAL.

Figure 1-17.—Isometric 45-degree squares, chamfers, and diagonals.

3. Practice similar projects until you have mastered the isometric representation of the rectangular solid.

4. Draw an isometric pipe diagram similar to that shown in figure 1-18. Draw fittings to a 45-degree angle instead of a 90-degree angle, as shown.

5. Draw a room 8 feet by 10 feet by 7 feet 6 inches high in an isometric representation with the ceiling and two walls removed. Use a scale of 1/4 inch = 1 foot. Show the walls as 6 inches thick.

DIMENSIONING AN ISOMETRIC DRAWING

An isometric drawing or sketch is dimensioned with extension and dimension lines nearly like a two-dimensional drawing. The extension lines extend from the drawing, so the dimension lines are parallel to the object line and of equal length to it.

To dimension the isometric drawing is more difficult because there is only a single view, and less room is available than on three separate views.

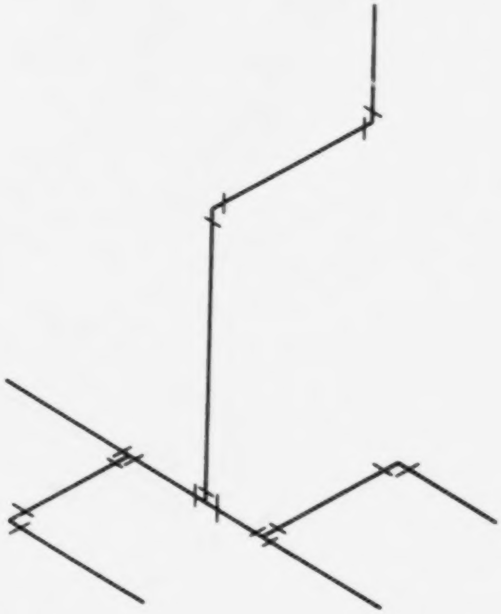


Figure 1-18.—Pipe diagram.

Figure 1-19 shows a dimensioned isometric drawing for part of a pipe hanger. In making the isometric pipe diagram, refer to the architect's plans and "rough in" sheets for accurate information.

Since pipe diagrams are measured from the center of one fitting to the center of the next fitting, it is possible to omit the extension and dimension lines by use of a notation, such as 13 inch c-c (center to center).

Pipe sizes must be added to the pipe diagram. The size of pipe is shown by a number near the line indicating the pipe, as shown in figure 1-20.

DIMENSIONING AN ISOMETRIC PIPE DIAGRAM

The purpose of an isometric pipe layout is best served by a simplified dimensioning system. Because few dimensions are shown, draw accurately to scale so the layout can be measured.

Practice dimensioning by redrawing the pipe diagram of figure 1-20 as an isometric pipe layout. Ensure the lengths are to scale, and dimension the pipe size accordingly. Also, make a list of fittings and pipe required.

SKETCHING PRACTICE

So far, the principles of reading prints and drawing sketches have been discussed. To practice these rules, look at the three isometric drawings in figure 1-21 and sketch three 3-view

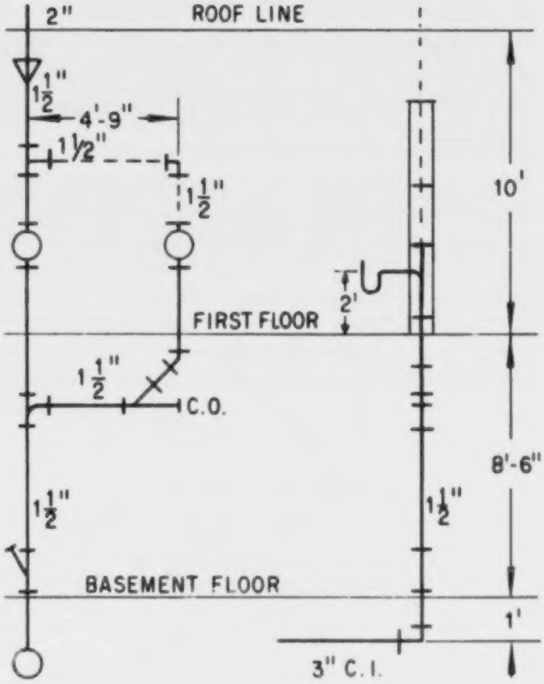


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Figure 1-20.—Pipe layout.

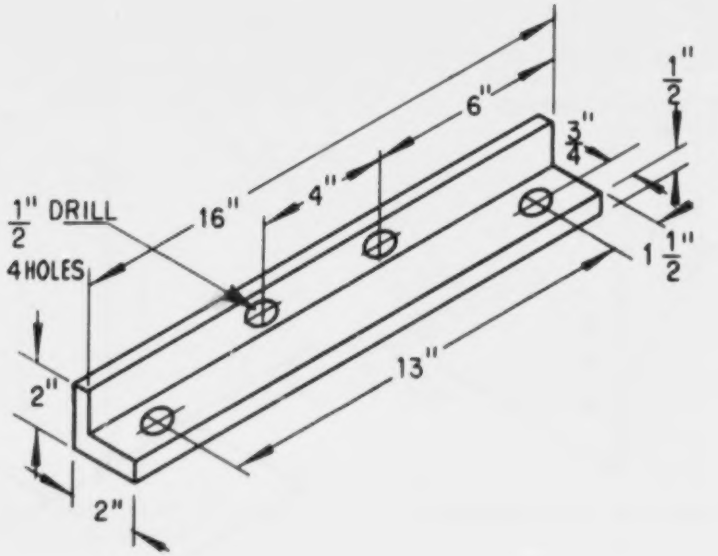

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Figure 1-19.—A 2- by 2- by 1/2-inch angle for pipe hanger.

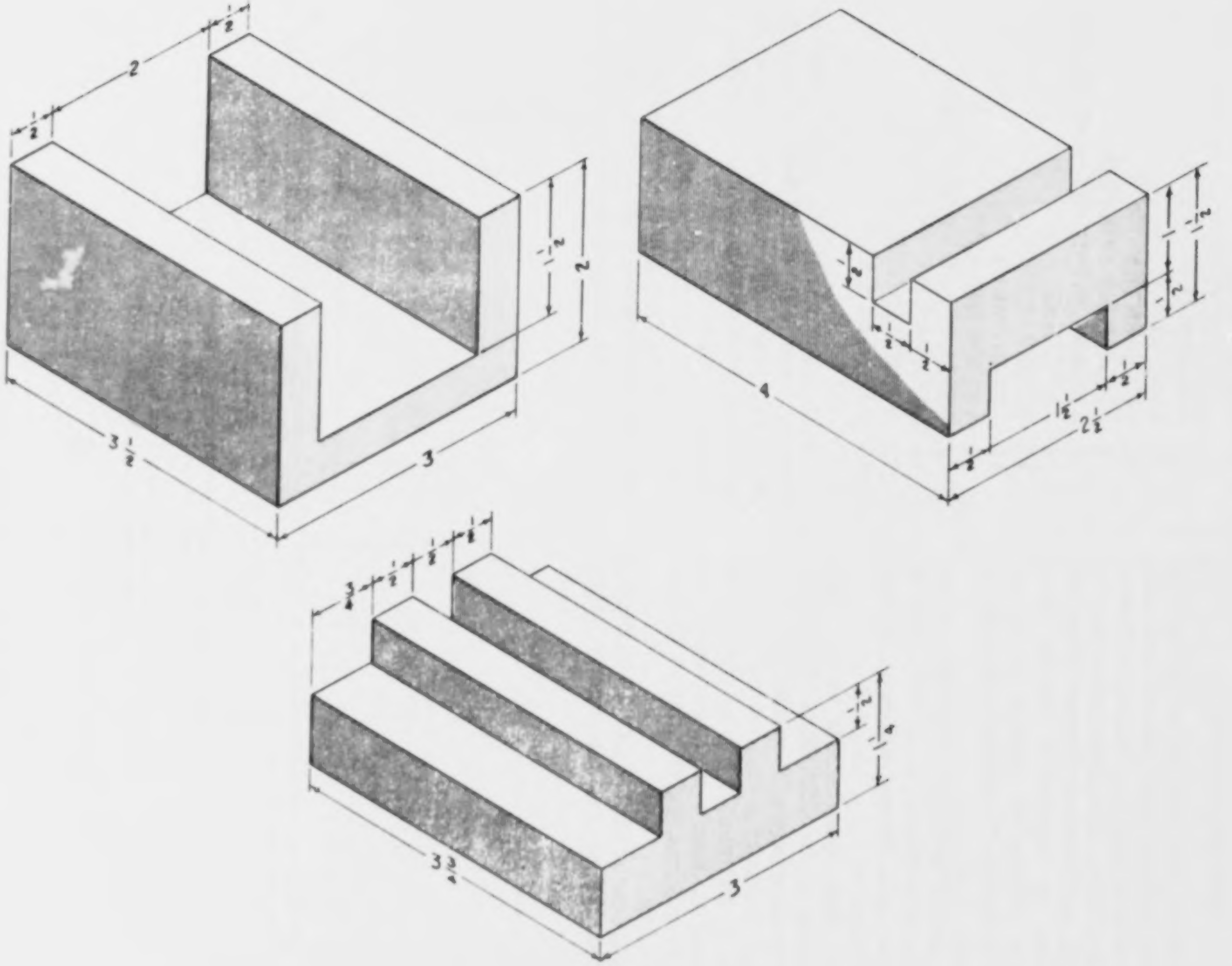
1/2
2
1/2
1/2
2
3 1/2
3
4
1/2
1/2
1/2
1
1/2
1/2
1 1/2
2 1/2
1/2
3/4
1/2
1/2
1/8
1/2
1 1/4
3 3/4
3

Figure 1-21.—Three isometric views to be drawn orthographically.

65.51

drawings properly dimensioned. (See fig. 1-22.) Now, make three isometric sketches properly dimensioned.

SPECIFICATIONS

Although the plans you will be working from usually have sufficient detail, you will need additional information regarding materials and methods of installation. This information may be found in the appropriate specifications. Plans and specifications go together to provide visual and written information about a project required by you, as the constructor, installer, or maintainer.

There are several types of specifications (commonly called **SPECS**), but you will work primarily with a project guide, Federal, Military, and NAVFAC specifications.

Project guide specifications usually begin with Division 1, the **GENERAL REQUIREMENTS** for the structure. They state the type of foundation, character of load-bearing members (wood frame, steel frame, concrete), type or types of doors and windows, types of mechanical and electrical installations, and the principal function of the building.

Next come the **SPECIFIC CONDITIONS** that are carried out by the constructors. These conditions are grouped in divisions under headings applying to each major phase of construction, as in the following typical list of divisions:

2. —SITE WORK
3. —CONCRETE
4. —MASONRY
5. —METALS
6. —CARPENTRY
7. —MOISTURE CONTROL
8. —DOORS, WINDOWS, AND GLASS
9. —FINISHES
10. —SPECIALTIES
11. —EQUIPMENT
12. —FURNISHINGS
13. —SPECIAL CONSTRUCTION
14. —CONVEYING SYSTEMS
15. —MECHANICAL
16. —ELECTRICAL.

Sections under one of these general categories generally begin with **GENERAL REQUIREMENTS** for that category and continue with the specific requirements. An example of a section of Division 15 follows.

In studying the guide specifications for plumbing which follow, study the drawing shown in figure 1-23, keeping in mind that these

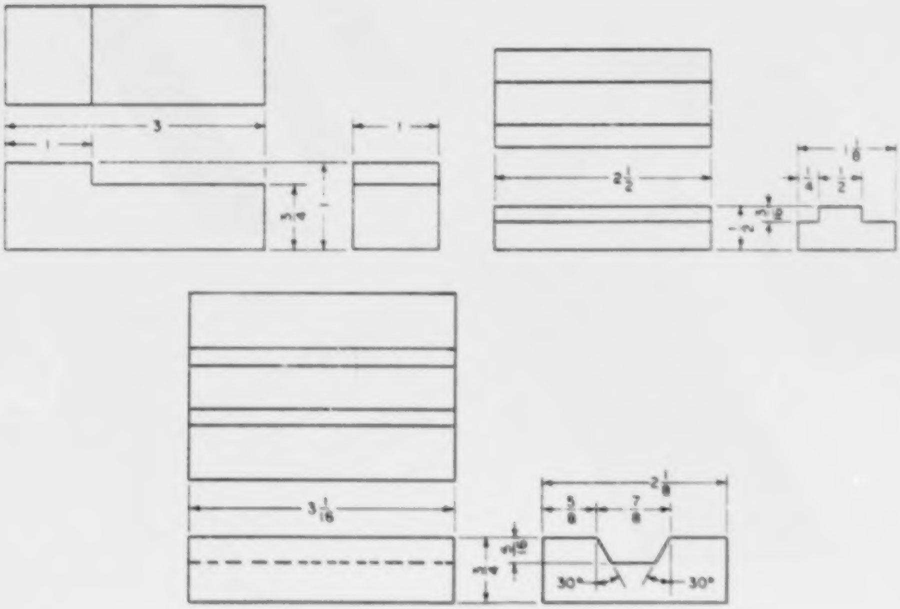

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Figure 1-22.—Three orthographic views to be drawn isometrically.

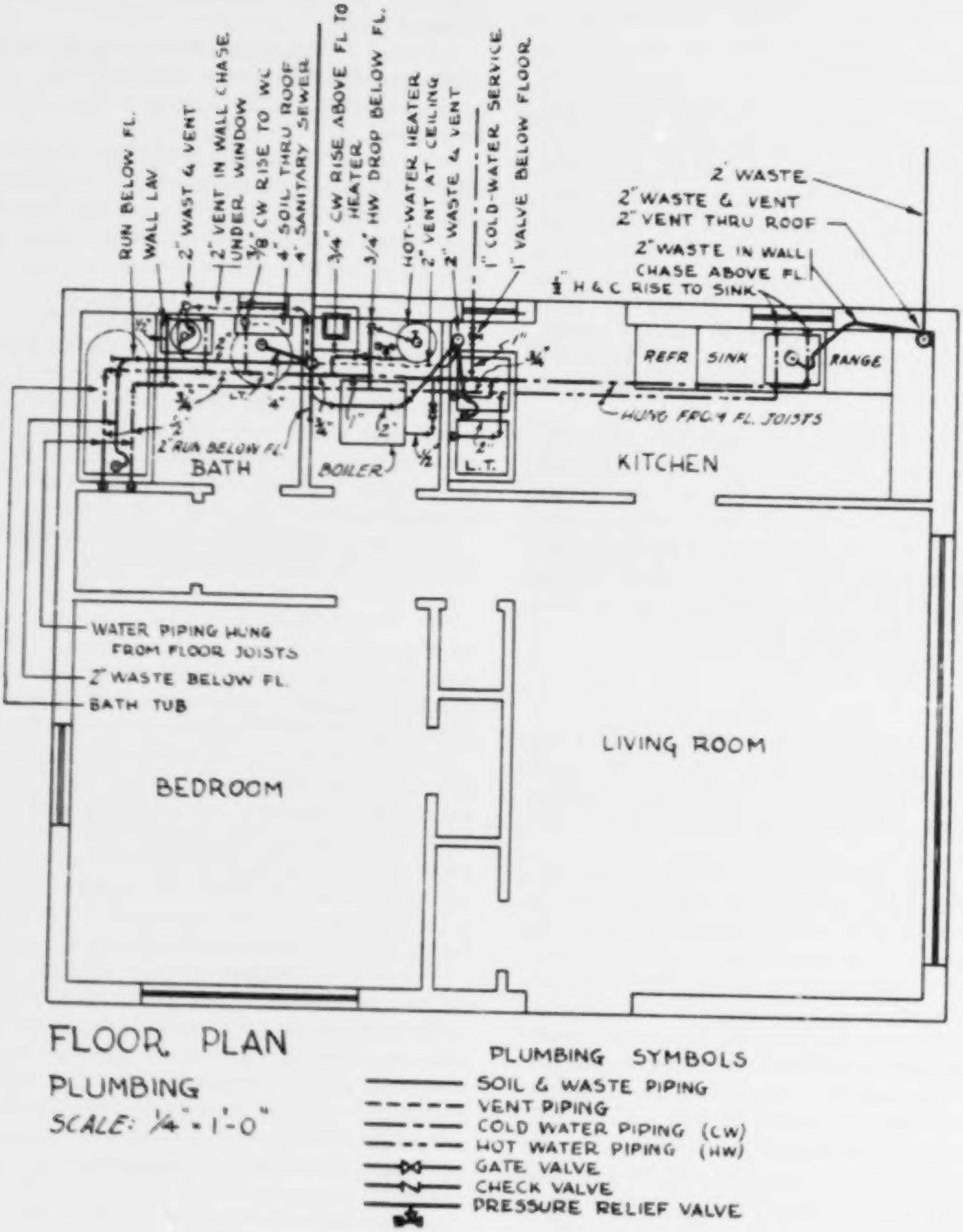
RUN BELOW FL.
WALL LAV
2" WAST & VENT
2" VENT IN WALL CHASE UNDER WINDOW
3/8" CW RISE TO WC
4" SOIL THRU ROOF
4" SANITARY SEWER
3/4" CW RISE ABOVE FL TO HEATER
3/4" HW DROP BELOW FL.
HOT-WATER HEATER
2" VENT AT CEILING
2" WASTE & VENT
1" COLD-WATER SERVICE
1" VALVE BELOW FLOOR
2" WASTE
2" WASTE & VENT
2" VENT THRU ROOF
2" WASTE IN WALL CHASE ABOVE FL.
1/2 H & C RISE TO SINK
REFR
SINK
RANGE
HUNG FROM FL. JOISTS
KITCHEN
2" RUN BELOW FL
BATH
BOILER
L.T.
WATER PIPING HUNG FROM FLOOR JOISTS
2" WASTE BELOW FL.
BATH TUB
BEDROOM
LIVING ROOM
FLOOR PLAN
PLUMBING
SCALE: 1/4" = 1'-0"
PLUMBING SYMBOLS
SOIL & WASTE PIPING
VENT PIPING
COLD WATER PIPING (CW)
HOT WATER PIPING (HW)
GATE VALVE
CHECK VALVE
PRESSURE RELIEF VALVE

Figure 1-23.—Typical plumbing layout for a small house.

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specifications are for this project and are listed as samples.

DIVISION 15—MECHANICAL

Section 15. 1a- Plumbing

15. 1a-01. **GENERAL REQUIREMENTS.** The work consists of a complete plumbing system, including the sanitary soil, waste and vent piping; cold- and hot-water supply piping, water meter (if required), plumbing fixtures, hot-water heater, and other appurtenances. The system must be inspected, tested, and approved by local governing plumbing codes before burying, concealing, or covering the various piping systems. Each system must be complete and ready for operation except as specified or indicated otherwise.

15. 1a-02. **SANITARY SEWER, BELOWGROUND** level, must be of extra heavy cast-iron soil piping and fittings of the bell-and-spigot type, extending 3 to 5 feet beyond the foundation wall and graded not less than 1/8 inch per foot. The joint will be made from a good grade of twisted oakum uniformly and well tamped into the joint and with a 1-inch depth of hot poured lead, made in one pouring, and caulked tight. All horizontal soil connections to the system must be accomplished by Y-fittings or combination Y and 1/8 bends. All changes in direction greater than a 1/8 bend must be of the long sweep pattern. Lines should be well supported to eliminate sagging. Backfilling will be well tamped in 6-inch layers.

15. 1a-03. **SANITARY SEWER, ABOVEGROUND** level, must be as specified for the belowground level, except waste lines and vent piping above the ground must be of zinc coated, standard-weight, screwed-end steel pipe and cast iron, recessed, long radius, screwed drainage fittings, and graded not less than 1/8 inch per foot. The sanitary sewer vent will extend full size through the roof for a distance of not less than 12 inches, where it must be flashed with suitable corrosion-resistant metal before the roofing is installed. A 4-inch cleanout will be provided slightly above the ground elevation at the base of the soil stack. All male screw ends will be coated with a good grade pipe joint compound before entering into fittings. The bathtub trap must be provided with a 3/4-inch brass, screw drain plug; all lines must be properly supported from the floor joists with suitable hangers. A closet-bowl floor connection must have a cast-iron closet-bowl floor flange with provisions for anchoring the brass closet-bowl bolts and an approved type of horn gasket. The finished joint must be absolutely leakproof, and the bowl will sit squarely on the finished floor.

15. 1a-04. **WATER PIPING BURIED IN THE GROUND** must be jointless, type "K," soft, copper tubing. No kinking of the tube will be allowed.

15. 1a-05. **WATER PIPING ABOVEGROUND** level must be type "L," hard copper tubing with solder-type fittings except that vertical lines may be of type "L," soft copper tubing. All tubing lines will be properly anchored to the floor joists to eliminate pipe sag and vibration and pitched to the main shutoff valve for draining, when necessary. A hose bibb will be provided at the rear of the building with a stop and waste located inside the foundation wall for winter cutoff and waste, and arranged for complete drainage of the line from the hose bibb. Slip-joint connections will not be permitted below the finished floor.

15. 1a-06. Fixtures must be of a reliable manufacturer and will be as follows:

(a) **KITCHEN SINKS** will have a left-hand drainboard and be of cast iron with a smooth, white, acid-resisting porcelain enamel finish, 54 inches long by 25 inches wide by 35 inches high from floor to top of rim. The trim will be chromium plated, including combination mixing faucets with a soap dish, a large basket-type strainer with a 1 1/2-inch tailpiece, and a 1 1/2-inch wall-type P-trap. Hot- and cold-water supply lines in the sink cabinet will be provided with copper tubing valves. The cabinet will be of a heavy gauge steel with a baked-on, white enamel finish and have at least two sliding drawers.

(b) **LAUNDRY TRAY** will be of the double compartment, cement type, 48 inches long by 20 inches wide by 32 inches high from floor to rim and be of a smooth cement mixture to withstand sudden temperature changes without cracking or leaking. Tubs will have a metal guard around the rim. The laundry tray will be complete with stand, combination mixing faucets with tray-mounting brackets, 1 1/2-inch tailpieces, and 1 1/2-inch wall-type P-tray. A copper tubing valve will be provided in each supply line.

(c) **WATER CLOSET** will be of white, vitreous china, close-coupled tank and bowl, complete with white seat and seat cover, and have a chromium, 3/8-inch, screwed, brass floor supply line with a chromium I. P. valve.

(d) **LAVATORY** will be cast iron with a white porcelain enamel finish. The trim will be chromium plated and include combination mixing faucets with a 1 1/4-inch tailpiece, pop-up waste, 1 1/4-inch wall trap, and 3/8-inch, screwed, brass floor supply lines with I. P. valves.

(e) The **TUB** will be of the built-in type, cast iron, with a white porcelain enamel finish. The trim will be chromium plated and include a built-in wall-type faucet complete with shower attachments, a curtain rod and pins, and a 1 1/2-inch trip-lever waste. Copper tubing valves will be provided on each supply inside the wall access door.

15. 1a-07. **WATER HEATER** must be of the electrical storage type with a capacity of not less than 52 gallons. It must be of an approved manufacturer with the underwriter's label attached. It will be provided with two thermostatically operated heating elements: a 15-kilowatt element located near the top of the tank and 1-kilowatt element located near the bottom of the tank. A 3/4-inch bronze, drain valve will be provided at the extreme bottom of the tank with a 3/4-inch hose connection. A 1/2-inch brass, combination temperature and pressure-relief valve with a discharge extending to the floor drain will be furnished. A copper tubing valve will be installed in the cold-water supply. Electrical work must conform to the local governing electrical codes.

15. 1a-08. A main **SHUTOFF VALVE** will be installed as indicated or specified. The 1-inch main shutoff valve must be accessible, of the stop and waste pattern with soldering-type ends, and the waste arranged for complete drainage of the entire water-supply system.

15. 1a-09. **WORKMANSHIP** will be performed in a first-class manner, observing all standards of good installation practices.

15. 1a-10. **TESTS** must be conducted on all plumbing systems to provide tightness of all piping joints. If leaks occur, they will be repaired immediately and the tests repeated. The soil, waste, and vent systems will be completely filled with water to the highest point before checking for leaks. The hot- and cold-water piping must be tested with water at 1 1/2 times the working pressure. After all tests have proved satisfactory, all the necessary adjustments on the faucets, traps, valves, and other specialties will be checked, so the entire system can be placed in normal operation.

15. 1a-11. **INSULATION.** All the piping and fittings subjected to freezing temperatures must be adequately insulated with a suitable frostproof covering well secured in place.

The project guide specifications, then, provide all the normally required information on the materials and methods of work to be used in completing a project that is not contained in the plans. There may be times when you will need to know more about the characteristics of materials listed in the bill of material. For example, if you cannot obtain a specified type of material or piece of equipment and want to substitute, you will need to know the characteristics of each in order to compare them before making the decision to substitute. This is where a knowledge of and access to Federal, Military, and NAVFAC specifications are important.

FEDERAL specifications are written technical descriptions of materials and supplies used by the Navy and other federal government agencies. They cover in detail the characteristics and compositions of these items, and are listed, along with military specifications, in numerical and alphabetical indices generally available to you.

MILITARY specifications are similar to federal specifications but are developed for use by the Department of Defense. Formerly called JAN (Joint Army and Navy) specifications, they have been revised to MIL-SPECS, using the same serial number as before.

The last of the specifications that you will most likely use are the **NAVFAC** specifications. These are developed by the Naval Facilities Engineering Command and cover the Naval Facilities Engineering Command and other items normally used for construction. They are listed as "Type Specs" and Standard Specifications in the *Specifications Used in Contracts for Public Works Manual*, NAVFAC P-34.

REFERENCES

Blueprint Reading and Sketching, NAVEDTRA 10077-F1, chaps 1, 2, 7, 8, and 10, Naval Education and Training Program Management Support Activity, Pensacola, Fla., 1988.

Engineering Aid 3 & 2, Vol. 1, NAVEDTRA 10634-C1, chaps 4, 5, and 8, Naval Education and Training Program Management Support Activity, Pensacola, Fla., 1985.

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CHAPTER 2

ROUGH-IN PLUMBING

Learning Objective: Recognize the importance of proper tool accountability and describe the procedures for rough-in plumbing.

"Roughing-in" as applied to plumbing and pipe fitting is a term used for the installation of concealed piping or fittings at the time a building is under construction or being remodeled. As the building nears completion, the final connections of fixtures are made.

Plans or blueprints show room dimensions and equipment locations, but they do not show at what elevations or locations piping must be stubbed through a wall for final connections.

Rough-in drawings are furnished by equipment suppliers, and these drawings show not only the correct location of the roughed-in piping but also show where to install any necessary backing boards behind the finished walls. A wall-hung lavatory hangs on a hanger or bracket, and this hanger, in turn, must be fastened to the wall using long wood screws that go through the plaster or drywall and into a backing board.

Roughing-in is probably the most important work for which a plumber is responsible. If the piping is not roughed-in correctly, the final connections may be difficult. You should not rely solely on past experience. You should refer to the specifications for the proper rough-in measurements so the piping used is of the correct size and terminates at a point where it can be connected to the fixture without additional work and materials.

TOOLS

As a Utilitiesman, you will be installing various types of equipment that requires the use of tools. You must understand the importance of using the proper tools for the proper job. For a better understanding of tools and their uses, read the training manual, *Tools and Their Uses*, NAVEDTRA 10085-B1. The following tool kits are available to the Utilitiesman from the Naval Construction Force, table of allowance (TOA):

80001 Kit, Plumbers: This kit contains the basic equipment and hand tools required for field installation of various plumbing systems.

80002 Kit, Plumber's Shop: This kit contains the basic equipment and hand tools required for establishing a base maintenance plumbing shop.

80005, Service Refrigeration: This kit contains the basic equipment and hand tools required for routine maintenance, recharging, and repair of various types of refrigeration units.

80055 Kit, Cast-Iron Pipe Installation: This kit contains the basic equipment and hand tools required for the installation of cast-iron piping.

TOOL ISSUE

You may be required to draw tools from the central toolroom (CTR) or the central storeroom (CSR). Procedures for issue and accounting of tools and replacement of broken or missing tools are established in the COMCBPAC/COMCBLANTINST 10290 series. You are responsible for the following:

- Maintaining the complete tool kit for which you signed
- Using and caring for tools assigned to you
- Preserving those tools in use and those not in use
- Securing assigned tools

- Accounting for tools
- Seeing that tools are returned to their proper place at the end of the day

You are required to conduct a biweekly inventory/inspection to ensure that tools are maintained properly and ready for use. You will be required to submit NAVSUP 1250-1 signed by your division/company or chief for lost or missing tools and worn-out or broken tools. You may also be required to start action on a survey form (NAVSUP 154). For help in filling out these forms, ask your crew leader, first-class supervisor, or chief.

TOOL USE

You must use tools properly and in the way they were designed to be used. Not only can you damage the equipment or materials you are working on, but you could injure someone else or yourself. Keep tools clean and free of grease, oil, and dirt. Use the right tools for the right job. When you are through with a tool, put it back in its proper place. Tools requiring maintenance must be turned into CTR and CSR for immediate replacement. Do not take chances. Normally, preventive maintenance is performed on all power tools at least monthly. Be sure to comply with your command's maintenance inspections. Plan ahead. Use the prepared preventive maintenance schedule you received to help in job production and save time lost to the inspection.

As mentioned before, you are responsible for all tools assigned to you. The tool user is also responsible for tool safety and accountability. If you borrow a tool, be sure you return it to its proper place. Report any problems you have with the tools. Remember tools are expensive. It also takes time to replace lost or broken tools.

SAFETY

Protect your hands from injury as directed by the applicable safety instructions whenever you use tools. You may be working under a severe handicap without the full use of both hands. Make it a habit to FOLLOW ALL SAFETY RULES.

Ten Rules of Safety

There are several important aspects of safety that should remain uppermost in your mind when you are on the job. The ten rules are as follows:

- LEARN the safe way of doing your job before you start.
- THINK safety, and ACT safely at all times.
- OBEY safety rules and regulations; they are for your protection.
- WEAR proper clothing and protective equipment.
- CONDUCT yourself properly at all times; horseplay is prohibited.
- OPERATE only the equipment you are authorized to use.
- INSPECT tools and equipment for safe condition before starting work.
- ADVISE your superior promptly of any unsafe conditions or practices.
- REPORT any injury immediately to your supervisor.
- SUPPORT your safety program and take an active part in safety meetings.

In addition to the above, there are several good tool habits to help you perform your work more efficiently and safely.

Tool Habits

"A place for everything and everything in its place" is just common sense. You cannot do an efficient, fast repair job when you have to stop and look around for each tool you need. The following rules, if followed, will make your job easier:

KEEP EACH TOOL IN ITS PROPER STORAGE PLACE. A tool is useless if you cannot find it. When you return each tool to its proper place, you will know where it is the next time you need it.

KEEP YOUR TOOLS IN GOOD CONDITION. Protect them from rust, nicks, burrs, and breakage.

KEEP YOUR TOOL ALLOWANCE COMPLETE. When issued a toolbox, you should ensure that each tool not actually being used is in it. If possible, the toolbox should be locked and stored in a designated area. To keep track of your tools, make an inventory listing of them, retain it in your toolbox, and check the listing after each job is completed. (See fig. 2-1.)

NOTE: Never leave your toolbox adrift where it could become a missile and cause injury to personnel nearby.

NAVAL MOBILE CONSTRUCTION BATTALION APR 23 87

	DRAWING ZONE	QTY	UI	WEIGHT	CUBE	ESTIMATED UNIT-$-VAL	ESTIMATED TOTAL-$-VAL
80001 KIT PLUMBERS (F/4 MEN)		5	ASSY/ECC	PER GRP/FAC		QTY 'B'	
9GD 3439-01-067-9299 TORCH OUTFIT SOLDERING AND HEATING PROPANE/ MAPP W/HOSE, REGULATOR, HANDLE AND 2-TIPS		1	EA	6.00	.35	87.96	87.96
9GD 3439-01-068-2003 TORCH AND HANDLE, HEATING, FOR USE W/ALL LP GASES INCLUDING MAPP GAS. USE W/NSN 3439-01-067-9299 FOR LARGE HEATING AND SOLDERING JOBS		1	EA	5.00	.25	161.89	161.89
9GD 3439-01-102-8629 SHIELD, HEAT AMPLIFIER, FITS SOLDERING TORCH TIP T-4 CONTAINED IN TORCH KIT NSN 3439-01-067-9299		1	EA	.25	.05	8.30	8.30
9ZD 4020-00-587-0994 CORD NYLON TWISTED 350FT		1	EA	.50	.20	2.66	2.66
9CD 4930-00-554-6778 OILER HAND PUMP 8 OZ		1	EA	5.00	.20	2.66	2.66
9QG 5110-00-186-4215 REAMER HAND 1/8 TO 2N FLUTED		1	EA	7.00	.16	85.07	85.07
9QG 5110-00-186-7107 CHISEL COLD 1/2		2	EA	.68	.01	.68	1.36
9QG 5110-00-221-8132 CHISEL COLD 5/8		2	EA	.68	.01	.78	1.56
9QG 5110-00-234-6539 FILE HAND BAST FLAT 12N		2	EA	2.18	.04	2.03	4.06
9QG 5110-00-236-3273 CHISEL COLD 7/8		2	EA	1.90	.02	1.44	2.88
9QG 5110-00-241-9153 FILE AMPAT HLFRD BAST 10		2	EA	1.00	.02	2.62	5.24
9QG 5110-00-277-4590 BLADE HACKSAW 18T 12LG (10 PER BD)		1	BD	.50	.01	3.21	3.21
9QG 5110-00-288-6521 CUTTER TUBE 3/8-2 5/8		1	EA	1.00	.15	17.12	17.12
9QG 5110-00-293-0090 SAWS NEST KEY-COMPS-NAIL		1	SE	2.00	.00	5.35	5.35

Figure 2-1.—Kit plumbers.

USE EACH TOOL ONLY ON THE JOB FOR WHICH IT WAS DESIGNED. If you use the wrong tool to make an adjustment, the end result will probable be unsatisfactory. For example, if you use a socket wrench that is a slightly oversized, you will round off the corners of the wrench or nut. If this rounded wrench or nut is not replaced immediately, the safety of your equipment may be jeopardized in an emergency. Does this sound exaggerated? Remember . . . for want of a nail, a kingdom was lost.

KEEP YOUR TOOLS WITHIN EASY REACH AND WHERE THEY CANNOT FALL ON THE FLOOR OR INTO MACHINERY. Avoid placing tools anywhere above machinery or electrical apparatus. Serious damage can result when a tool falls into the machinery after the equipment is energized.

NEVER USE DAMAGED TOOLS. A battered screwdriver may slip and spoil the screw slot, damage other parts, or cause painful injury. A gauge that is strained out of shape can result in inaccurate measurements.

Remember, the efficiency of a craftsman is determined to a great extent by the condition of his or her tools and the manner in which they are maintained. Anyone watching a skilled craftsman at work notices the care and precision with which tools of the trade are being used.

The care of hand tools should follow a pattern similar to personal articles; that is, always keep hand tools clean and free of dirt, grease, and other foreign matter. After use, return tools promptly to their proper place in the toolbox. Improve your efficiency by organizing tools so those used most frequently can be reached easily without digging through the entire contents of the toolbox. Avoid accumulating unnecessary junk.

PLUMBING FIXTURES

Plumbing fixtures are the receptacles into which wastes are placed before being discharged into the sewer. There are many types and styles of fixtures, some are general, while others are for hospitals, prisons, or similar institutions. Many plumbing fixtures are constructed solely of vitreous china, iron, or porcelain-covered steel. Be careful in handling, installing, and repairing such fixtures. Military installations usually are planned to house large numbers of personnel, and the plumbing fixtures ordinarily are installed in batteries. The actual installation of a fixture has a hard-and-fast rule; either the manufacturer states how it is to be done or specifications state the so-called "roughing-in" measurements of the fixture in question. Sometimes you may have to design and lay out a fixture or battery of fixtures. You must know what water supplies and stack sizes are needed and work these into your design.

Standard plumbing fixtures are individually tested and the amount of liquid waste that can be discharged through their outlet orifices in a given interval is measured. When we learned that the washbasin, one of the smaller fixtures, discharges 1 cubic foot of water per minute, we had the basis for the fixture unit system. One fixture unit of a known liquid discharges 1 cubic meter of water per minute or about 7 1/2 gallons. Even though 7 1/2 gallons is not indicated in table 2-1, we chose that value to come up with an even meter. Try this one. How many flushings of a urinal equal five flushings of a water closet or toilet? Five or six? The fixture unit value for different plumbing fixtures is indicated in table 2-1.

Each plumbing fixture is equipped, of course, with a waste pipe of sufficient capacity to carry off quickly and quietly all water supplied to it. A plumbing fixture must also be furnished with water at a rate of flow that will fill it within a reasonable time.

As a general rule, the following supply pipe diameters are recommended: water closet tank, one-half inch; urinal equipped with flushing valve, three-fourth inch; laundry tubs, one-half inch; kitchen sink, one-half inch; slop sink, one-half inch; drinking fountain, one-half inch; and shower, one-half inch.

Table 2-1.—Plumbing Fixture Unit Values

Fixture	Units
Lavatory or washbasin	1
Kitchen sink	2
Bathtub	2
Laundry tub	2
Combination fixture	3
Urinal	5
Shower bath	2
Floor drain	1
Slop sink	3
Water closet	6
180 square feet of roof drained	1

Figures 2-2 through 2-7 show single-line drawings of the rough-in measurements for various fixtures. Remember, before you can measure for rough-in plumbing, you must identify the fixtures to be installed.

Service connections for steam radiators depend upon the sizes to be installed and the location of each. The same holds true for water tanks being used for storing or heating.

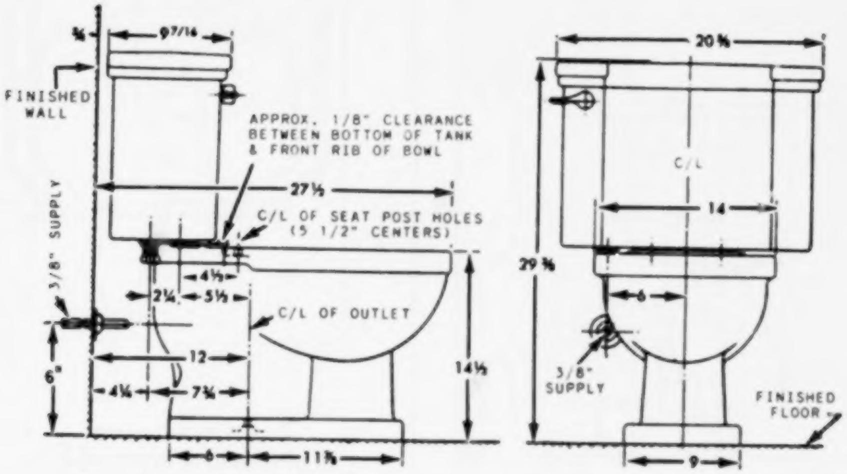

¾
9 7/16
FINISHED WALL
APPROX. 1/8" CLEARANCE BETWEEN BOTTOM OF TANK & FRONT RIB OF BOWL
27½
C/L OF SEAT POST HOLES (5 1/2" CENTERS)
3/8" SUPPLY
4½
2¼
5½
C/L OF OUTLET
12
6"
4¼
7¾
14½
6
11⅞
20⅝
C/L
14
29⅝
6
3/8" SUPPLY
FINISHED FLOOR
9

Figure 2-2.—Rough-in measurements of one type of water closet.

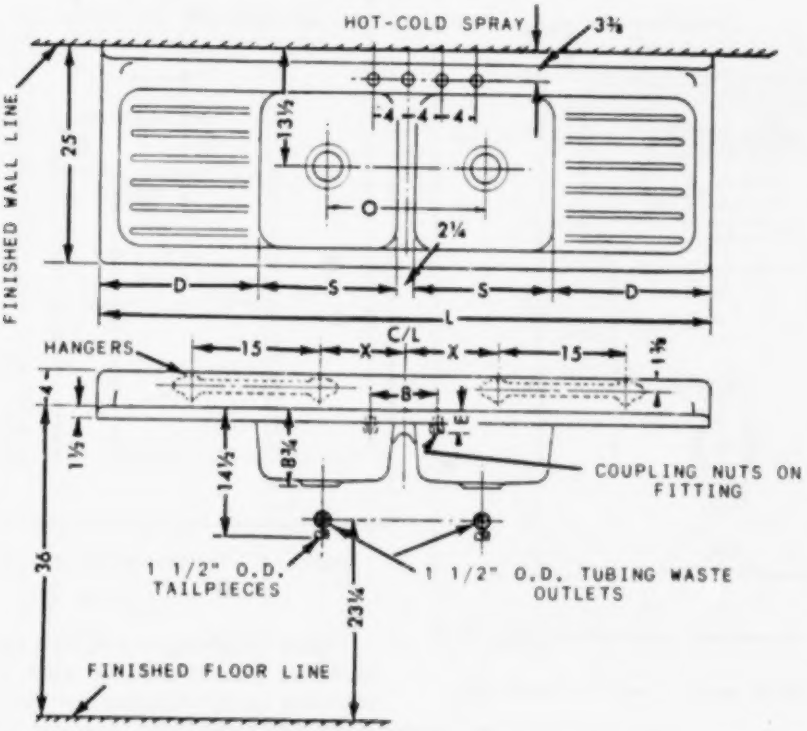

HOT-COLD SPRAY
3⅜
FINISHED WALL LINE
25
13½
4
4
4
O
2¼
D
S
S
D
L
C/L
HANGERS
15
X
X
15
1⅝
4
B
E
1½
8¾
14½
COUPLING NUTS ON FITTING
36
1 1/2" O.D. TAILPIECES
1 1/2" O.D. TUBING WASTE OUTLETS
23¼
FINISHED FLOOR LINE

Figure 2-3.—Rough-in measurements of one type of sink.

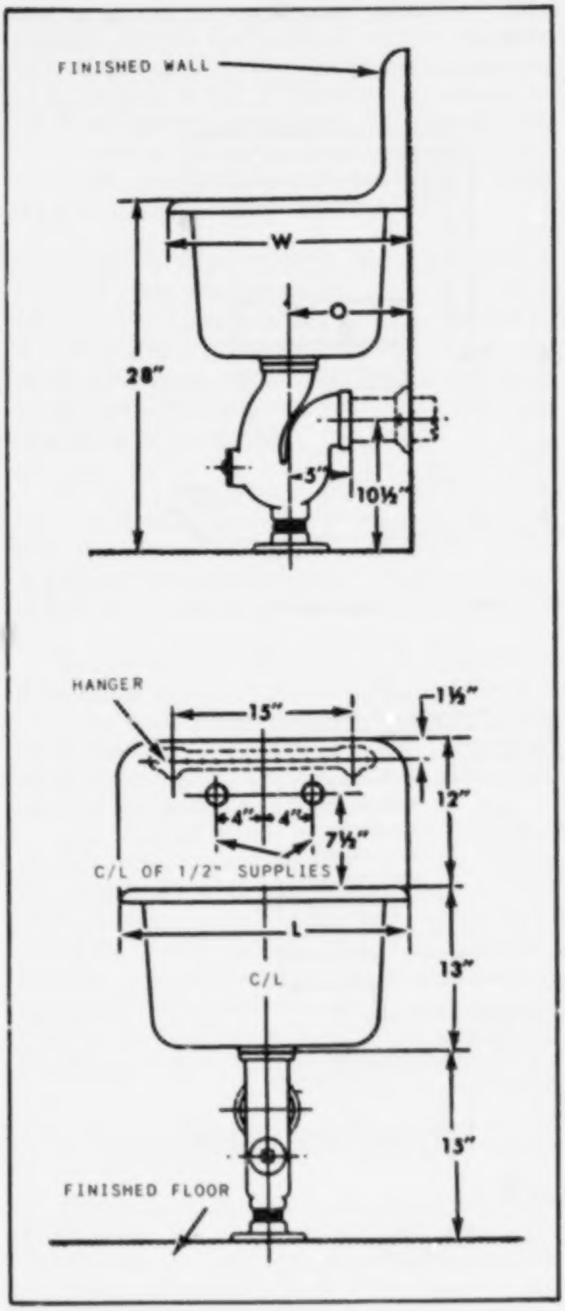

FINISHED WALL
W
O
28"
5"
10½"
HANGER
15"
1½"
12"
4"
4"
7½"
C/L OF 1/2" SUPPLIES
L
C/L
13"
15"
FINISHED FLOOR

Figure 2-4.—Rough-in measurements of a service sink.

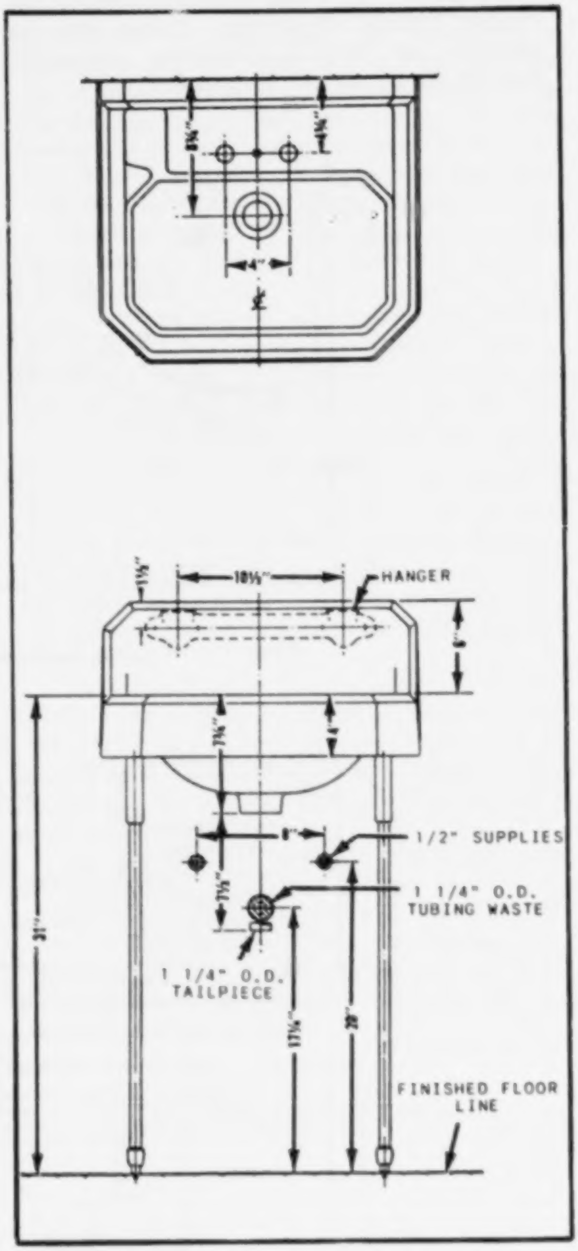

4"
℄
10½"
HANGER
6"
4"
8"
1/2" SUPPLIES
1 1/4" O.D.
TUBING WASTE
7½"
1 1/4" O.D.
TAILPIECE
31"
20"
FINISHED FLOOR
LINE

Figure 2-5.—Rough-in measurements of a lavatory.

After roughing-in you can easily install the plumbing fixtures and trim work. Instructions are provided in this chapter for the installation of various fixtures and accessories. Of course every type of fixture cannot be discussed; but if you

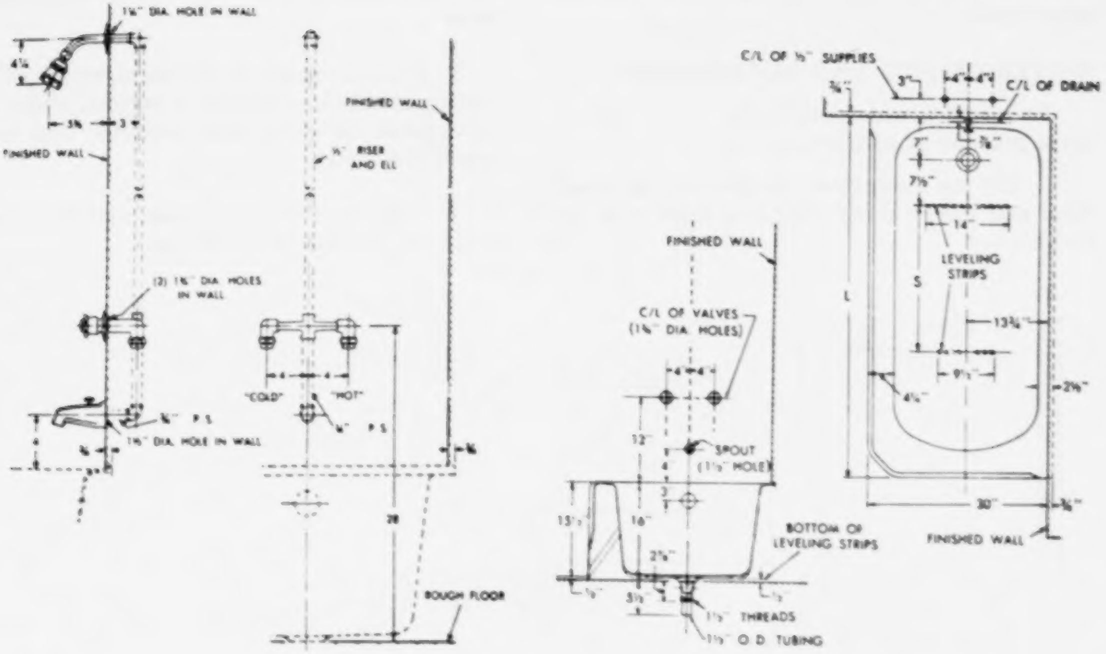

1¼" DIA. HOLE IN WALL
4½
3⅞
3
FINISHED WALL
(2) 1⅛" DIA. HOLES IN WALL
½" P.S.
1⅛" DIA. HOLE IN WALL
FINISHED WALL
½" RISER AND ELL
"COLD"
"HOT"
½" P.S.
28
ROUGH FLOOR
FINISHED WALL
C/L OF VALVES (1⅛" DIA. HOLES)
4" 4"
12"
SPOUT (1½" HOLE)
4"
3"
13½"
16"
2⅞"
3½"
BOTTOM OF LEVELING STRIPS
1½" THREADS
1½" O.D. TUBING
C/L OF ½" SUPPLIES
¾"
3"
4" 4"
C/L OF DRAIN
7"
⅞"
7½"
14"
LEVELING STRIPS
L
S
13¾"
9½"
4½"
2⅛"
30"
⅞"
FINISHED WALL

Figure 2-6.—Rough-in measurements of a tub and shower combination.

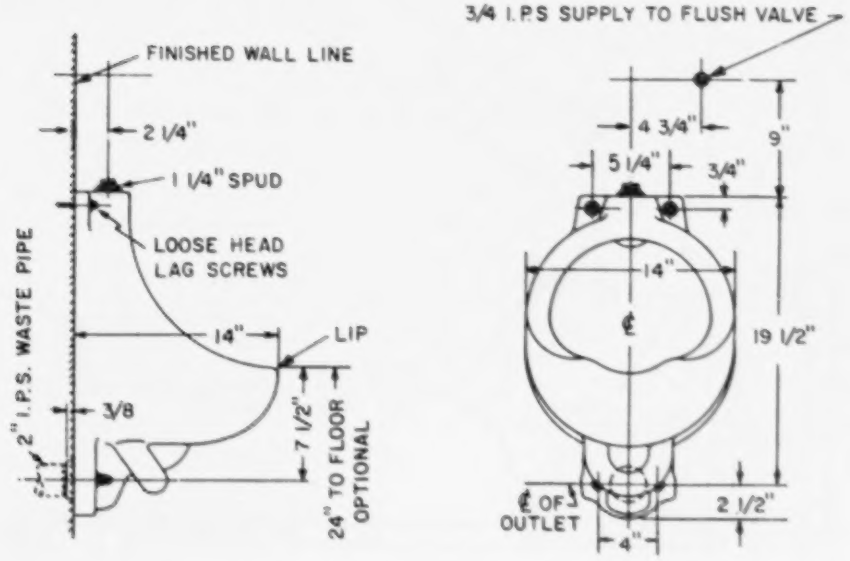

FINISHED WALL LINE
2 1/4"
1 1/4" SPUD
LOOSE HEAD LAG SCREWS
14"
LIP
3/8
2" I.P.S. WASTE PIPE
7 1/2"
24" TO FLOOR OPTIONAL
3/4 I.P.S SUPPLY TO FLUSH VALVE
4 3/4"
9"
5 1/4"
3/4"
14"
℄
19 1/2"
℄ OF OUTLET
2 1/2"
4"

Figure 2-7.—Rough-in measurements of a wall-hung urinal.

learn to install those covered in figures 2-8 through 2-10, you should have little difficulty with the other types.

WATER CLOSET AND ACCESSORIES

To install a water closet (fig. 2-11), follow these procedures as a general rule.

1. Slip the water closet flange over the closet bend and slide it down until it is level with the finish floor.

2. Prepare the joint for a lead-caulked joint; pour and caulk the water closet flange to the closet bend.

3. With hammer and cold chisel, break off the portion of the closet bend that projects above the water closet flange. Do not break the closet bend below the flange.

4. Place the two brass closet hold-down bolt heads in the slots of the flange.

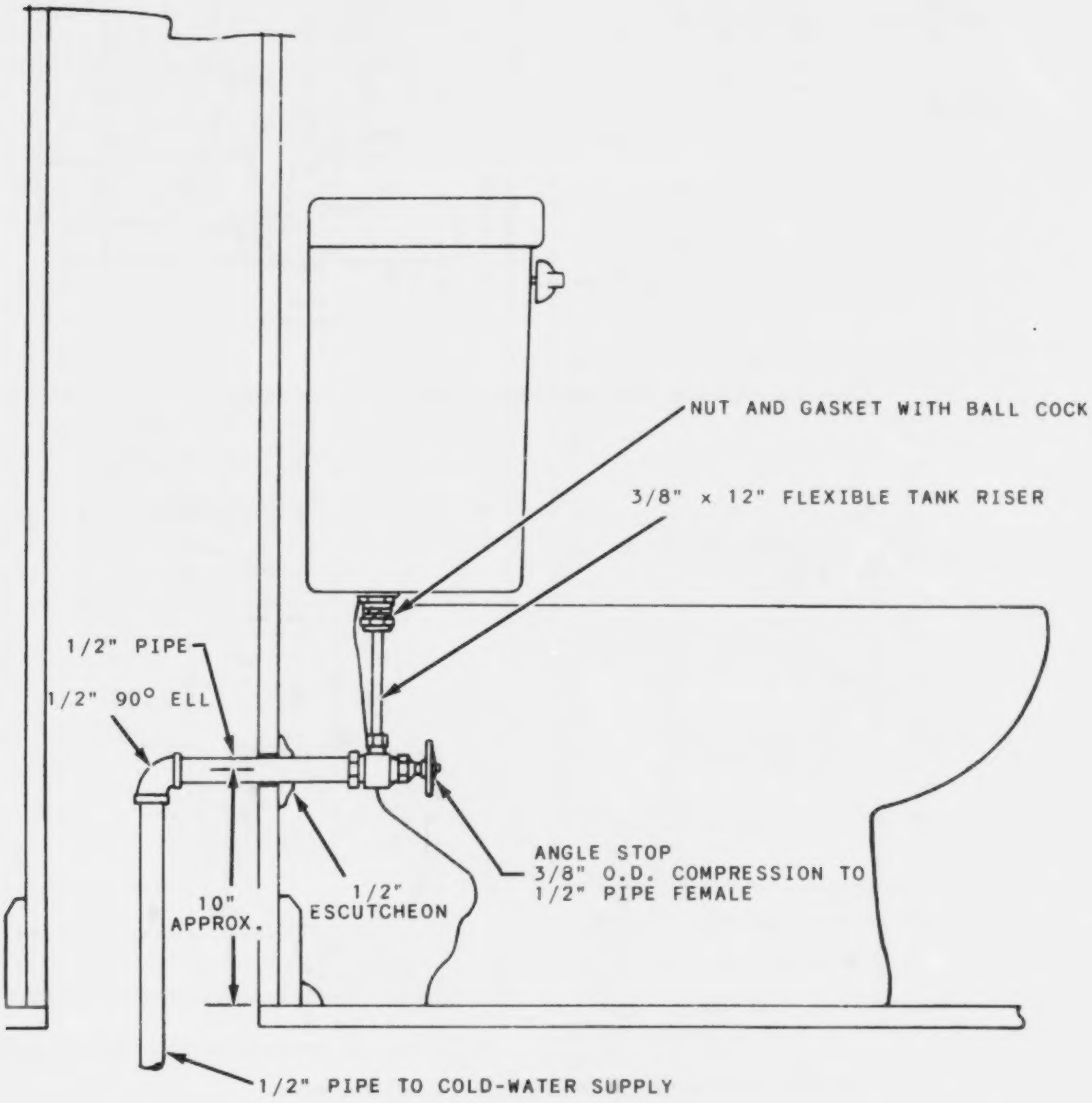
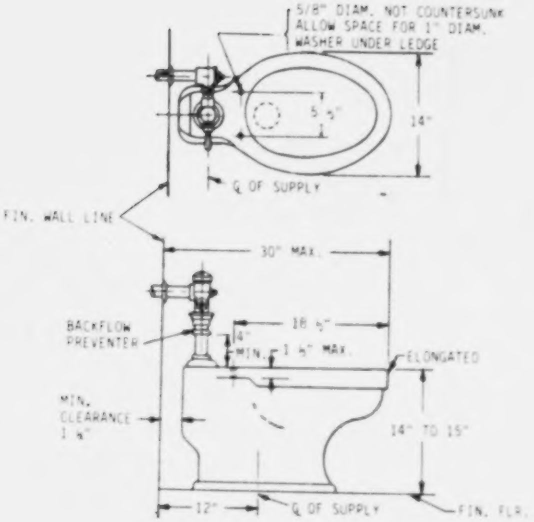
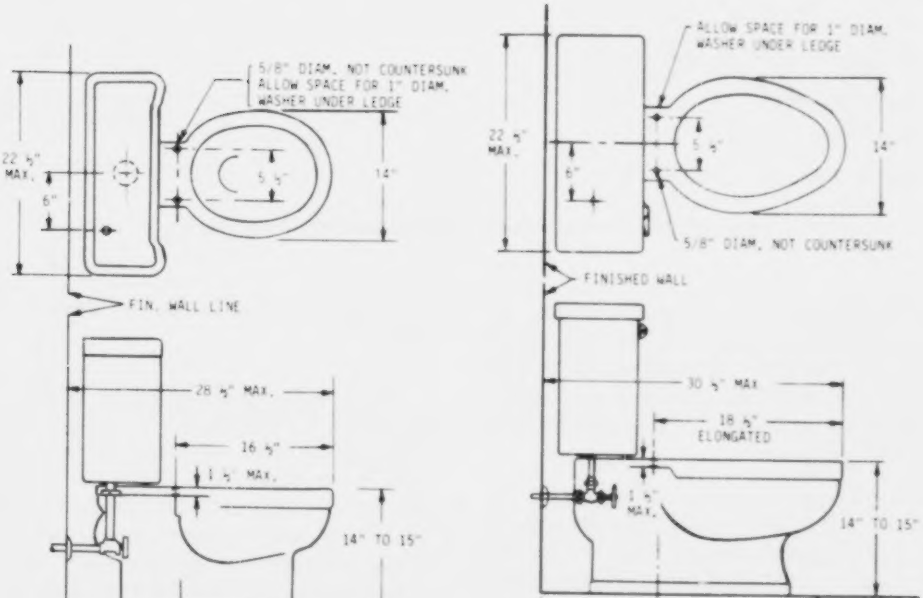

NUT AND GASKET WITH BALL COCK
3/8" x 12" FLEXIBLE TANK RISER
1/2" PIPE
1/2" 90° ELL
ANGLE STOP
3/8" O.D. COMPRESSION TO
1/2" PIPE FEMALE
10"
APPROX.
1/2"
ESCUTCHEON
1/2" PIPE TO COLD-WATER SUPPLY

Figure 2-8.—Water closet (two-piece).



5/8" DIAM. NOT COUNTERSUNK
ALLOW SPACE FOR 1" DIAM.
WASHER UNDER LEDGE
5 ½"
14"
℄ OF SUPPLY
FIN. WALL LINE
30" MAX.
BACKFLOW PREVENTER
18 ½"
4" MIN.
1 ½" MAX.
ELONGATED
MIN. CLEARANCE 1 ½"
14" TO 15"
12"
℄ OF SUPPLY
FIN. FLR.

FLUSH-VALVE SIPHON-JET
WATER CLOSET COMBINATION



5/8" DIAM. NOT COUNTERSUNK
ALLOW SPACE FOR 1" DIAM.
WASHER UNDER LEDGE
22 ½" MAX.
6"
5 ½"
14"
FIN. WALL LINE
28 ½" MAX.
16 ½"
1 ½" MAX.
14" TO 15"
12"
℄ OF OUTLET
FIN. FLR.
ALLOW SPACE FOR 1" DIAM.
WASHER UNDER LEDGE
22 ½" MAX.
6"
5 ½"
14"
5/8" DIAM. NOT COUNTERSUNK
FINISHED WALL
30 ½" MAX
18 ½" ELONGATED
1 ½" MAX.
14" TO 15"
12"
℄ OF OUTLET
FINISHED FLOOR LINE

CLOSE-COUPLED REVERSE TRAP
WATER CLOSET COMBINATION

CLOSE-COUPLED SIPHON-JET
WATER CLOSET COMBINATION

Figure 2-9.—Water closets (flush-valve and close-coupled).

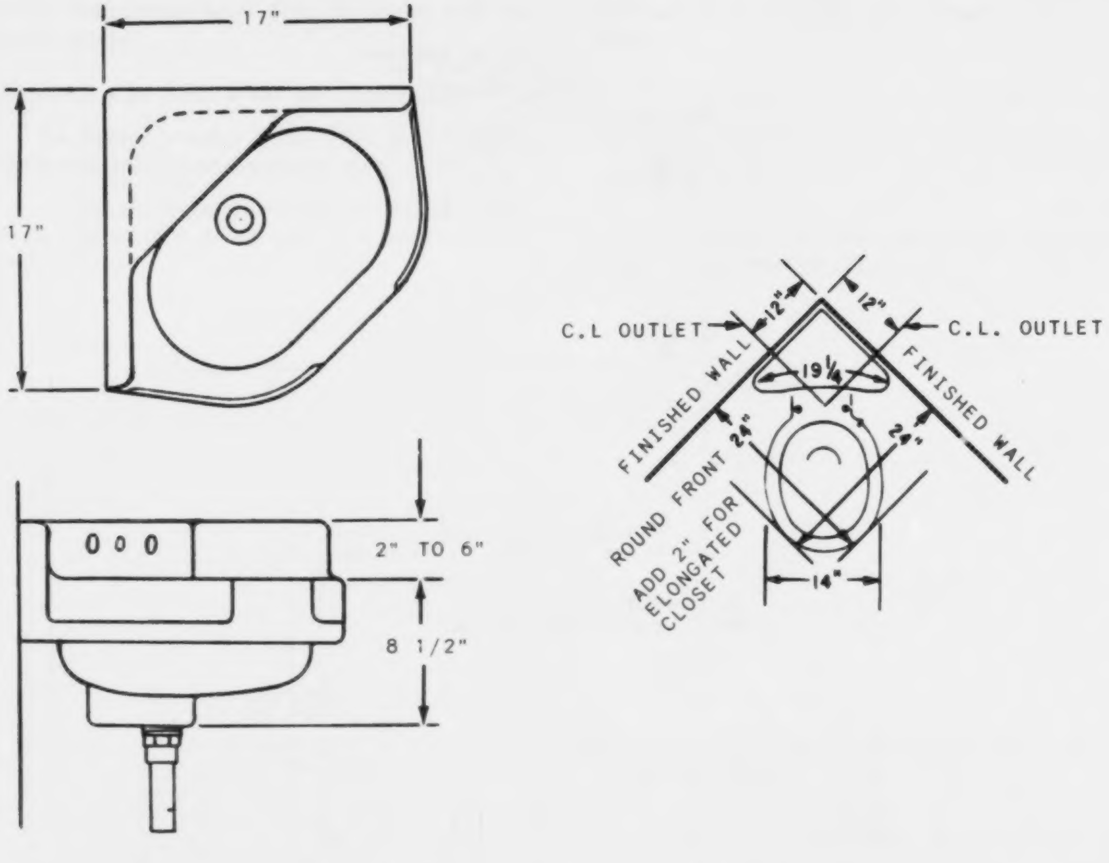


Figure 2-10.—Corner-mounted fixtures (sink and water closet).

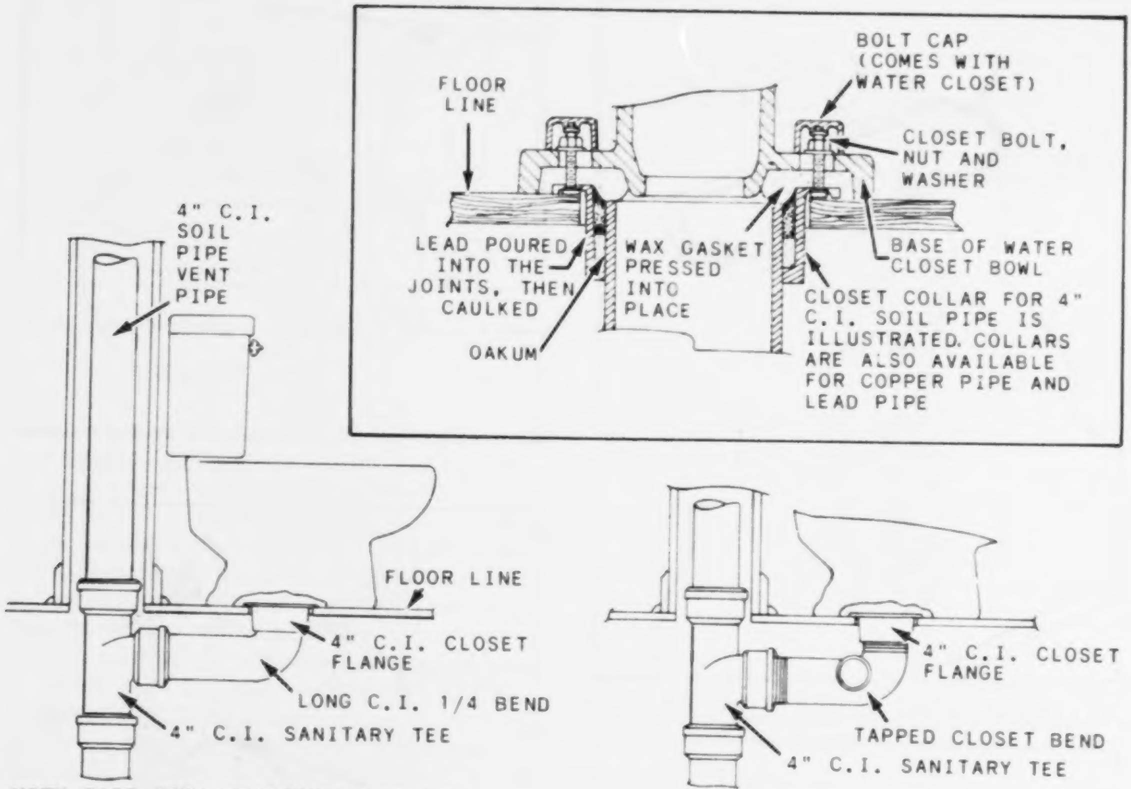
5. On the bottom of the water closet, as shown in view A, figure 2-12, slip the preformed sealing ring over the horn to form a sealing gasket for the water closet against the face of the flange. Do not use putty as it will dry out and leave a possible sewer gas leak.

6. Turn the water closet bowl right side up and set it on the flange with the horn projecting down into the flange. In setting the bowl on the flange, as shown in view B, figure 2-12, guide the two hold-down bolts up through the bolt holes on either side of the base of the water closet. Using your full weight, press down and twist slightly to settle the bowl and the wax ring into position. The bowl should be perfectly level when settled. Check for level. If off level, install a wedge.

7. Install nuts on the hold-down bolts and tighten them alternately. Do not overtighten them as this may crack the base of the water closet.

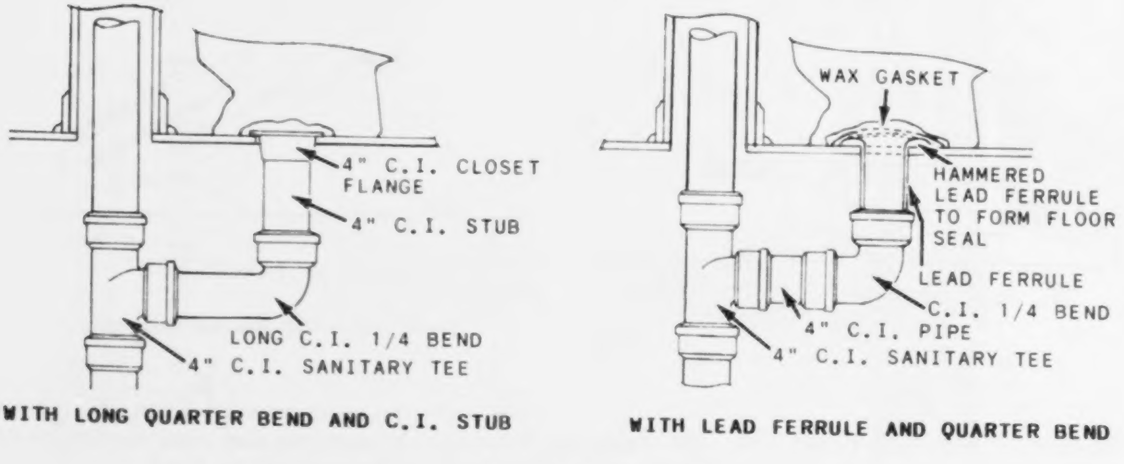
8. A wall-mounted water closet, as shown in view A, figure 2-13, is attached to the wall by a chair carrier, similar to the one shown in view B, figure 2-13. The chair carrier is positioned and bolted to the floor. The foot carries the weight of the entire closet independent of the walls and drainage connections. A standard fitting is used to connect the drain and the closet bowl after the chair carrier is bolted down. The fitting is for 4-inch-diameter soil pipe. The bolt holes in the chair carrier are slotted to facilitate installation of the closet bowl.

When mounting a close-coupled tank on a closet bowl, note that two bolts hold the tank on


BOLT CAP (COMES WITH WATER CLOSET)
FLOOR LINE
CLOSET BOLT, NUT AND WASHER
LEAD POURED INTO THE JOINTS, THEN CAULKED
WAX GASKET PRESSED INTO PLACE
BASE OF WATER CLOSET BOWL
CLOSET COLLAR FOR 4" C.I. SOIL PIPE IS ILLUSTRATED. COLLARS ARE ALSO AVAILABLE FOR COPPER PIPE AND LEAD PIPE
OAKUM
4" C.I. SOIL PIPE VENT PIPE
FLOOR LINE
4" C.I. CLOSET FLANGE
LONG C.I. 1/4 BEND
4" C.I. SANITARY TEE
4" C.I. CLOSET FLANGE
TAPPED CLOSET BEND
4" C.I. SANITARY TEE

WITH CAST-IRON DRAINAGE FITTINGS

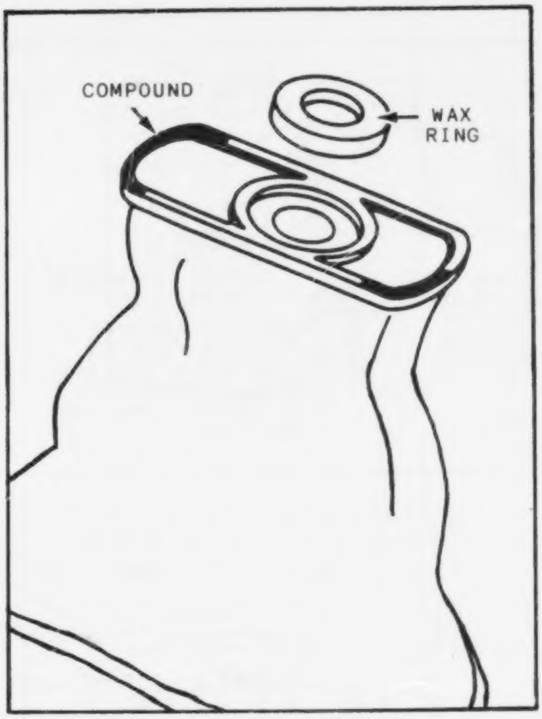
WITH TAPPED CLOSET BEND


4" C.I. CLOSET FLANGE
4" C.I. STUB
LONG C.I. 1/4 BEND
4" C.I. SANITARY TEE
WAX GASKET
HAMMERED LEAD FERRULE TO FORM FLOOR SEAL
LEAD FERRULE
C.I. 1/4 BEND
4" C.I. PIPE
4" C.I. SANITARY TEE

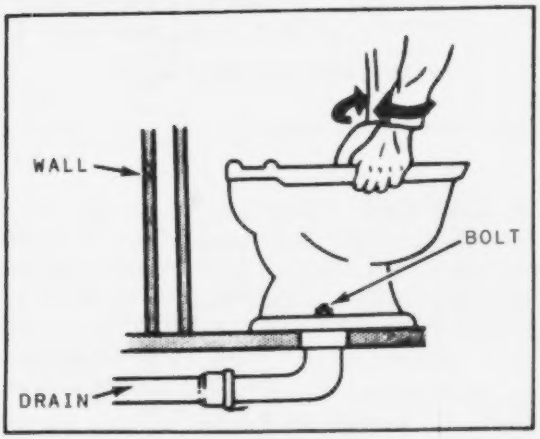
WITH LONG QUARTER BEND AND C.I. STUB

WITH LEAD FERRULE AND QUARTER BEND

Figure 2-11.—Water closet installation.

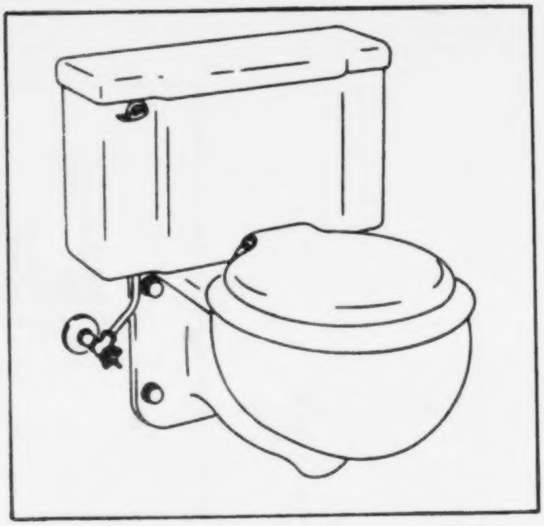


A. INSTALLING A WAX RING GASKET

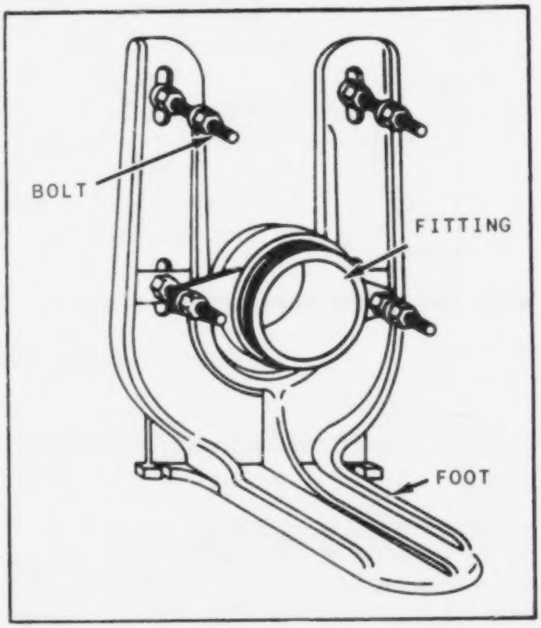


B. PLACING THE CLOSET BOWL

Figure 2-12.—Setting a closet bowl.



A. WALL-MOUNTED WATER CLOSET



B. CHAIR CARRIER FOR A WALL-HUNG WATER CLOSET

Figure 2-13.—Wall-mounted water closet.

the bowl. Figure 2-14 shows how. The water-supply pipe is between the bolts and drops the water directly into the bowl. A specially designed gasket is installed between the tank and bowl to make the connection waterproof. The bolts are tightened from underneath the closet bowl. Do not apply too much pressure when you tighten these bolts because you may crack the bottom of the tank or the back of the bowl.

After the tank is firmly attached to the bowl, connect the water-supply pipe to the tank inlet with a jiffy connector, as shown in figure 2-15. The jiffy connector used here is the same as the

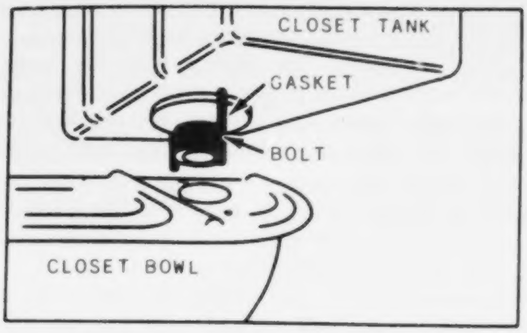


Figure 2-14.—Mounting a close-coupled tank on a closet bowl.

connector used to connect the water supply to the faucets of a lavatory.

Cold water for flushing is supplied to a water closet by a flush valve or a closet tank. No tank is needed with a flush valve. A flush valve comes in the diaphragm type and the piston type. Flush valves require less water than tank valves for flushing and can be flushed sooner after operation. A flush valve can be reflushed just seconds later.

A backflow preventer, such as the type shown in figure 2-16, should be installed on the discharge side of a flushometer. A backflow preventer should be installed on the supply line of a float valve in a water closet tank if the tank outlet is below the flood level rim of the closet bowl.

A detail of a diaphragm type of flushing valve is shown in figure 2-17. The diaphragm type of

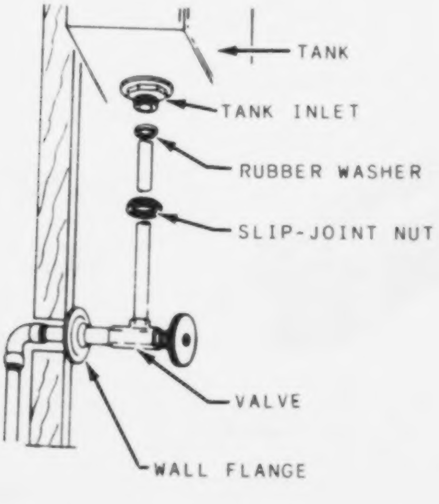
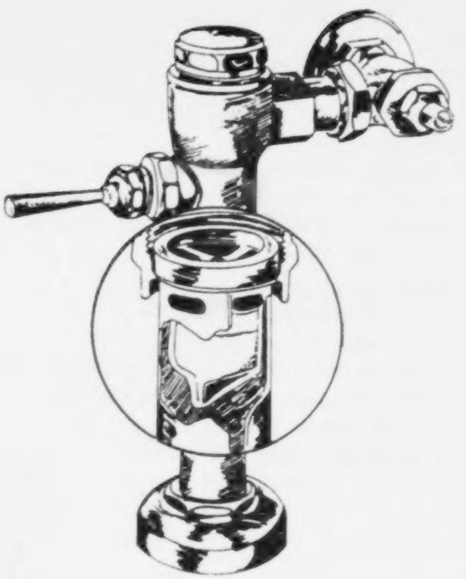


Figure 2-15.—Closet tank water-supply line.



54.477

Figure 2-16.—Flushometer valve showing enlarged flow of a backflow preventer.

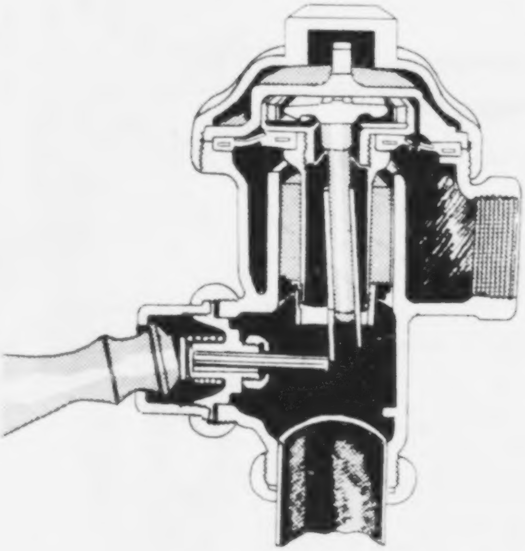


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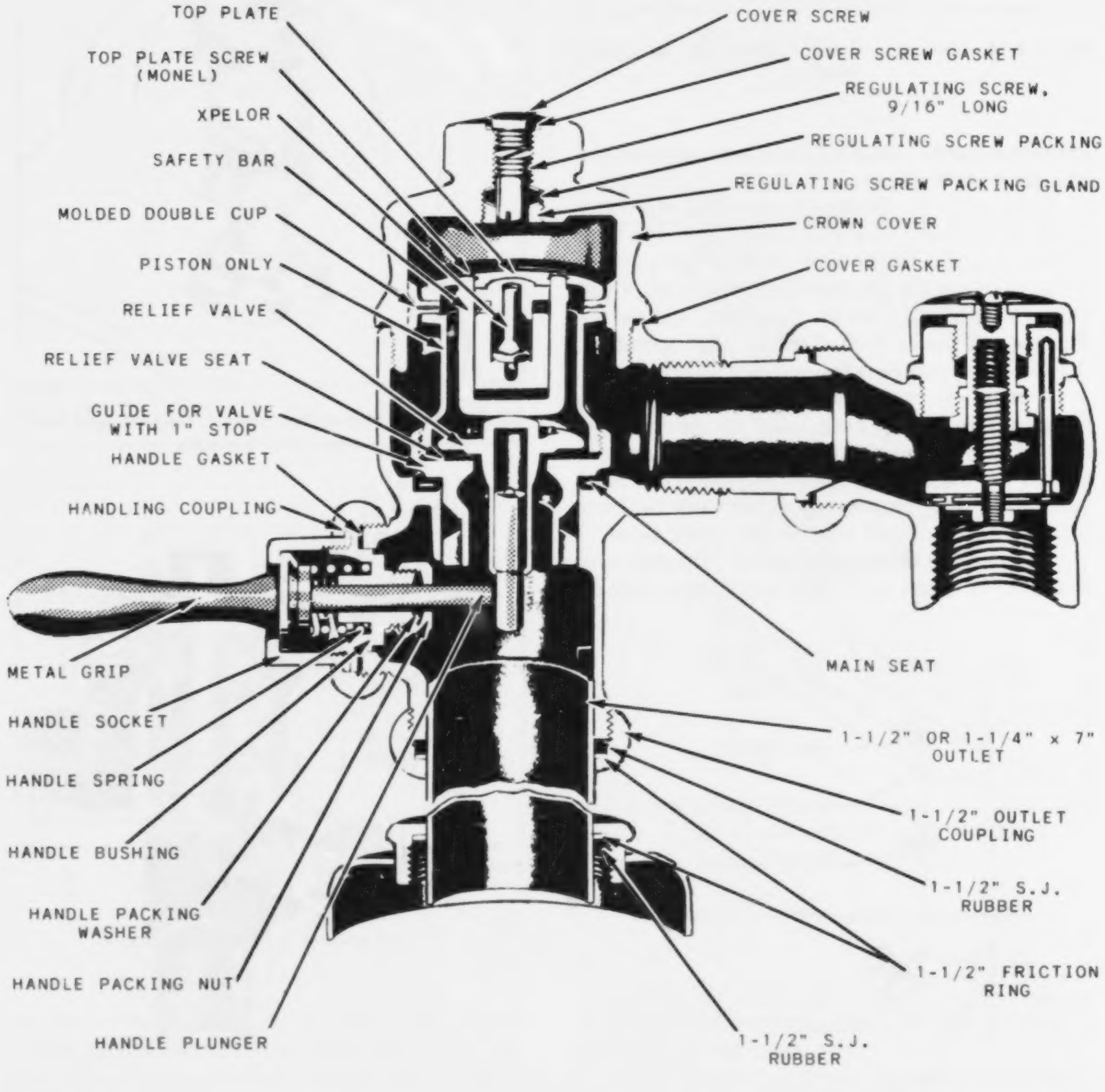
Figure 2-17.—Diaphragm type of flushing valve.

valve consists of an upper and lower chamber. These chambers are separated by the diaphragm and relief valve. The lower chamber is connected directly to the incoming water supply. This incoming water is the flushing water and also the water that shuts off the valve after the flushing period. The valve is flushed by the diaphragm and the water pressure in the upper chamber. Water is forced into the upper chamber through a small orifice (hole) in the diaphragm. Water pressure passing through this orifice into the upper chamber creates the pressure required to force the diaphragm down and to shut off the flushing water. By moving the flushing handle, the relief


TOP PLATE
TOP PLATE SCREW (MONEL)
XPELOR
SAFETY BAR
MOLDED DOUBLE CUP
PISTON ONLY
RELIEF VALVE
RELIEF VALVE SEAT
GUIDE FOR VALVE WITH 1" STOP
HANDLE GASKET
HANDLING COUPLING
METAL GRIP
HANDLE SOCKET
HANDLE SPRING
HANDLE BUSHING
HANDLE PACKING WASHER
HANDLE PACKING NUT
HANDLE PLUNGER
COVER SCREW
COVER SCREW GASKET
REGULATING SCREW, 9/16" LONG
REGULATING SCREW PACKING
REGULATING SCREW PACKING GLAND
CROWN COVER
COVER GASKET
MAIN SEAT
1-1/2" OR 1-1/4" x 7" OUTLET
1-1/2" OUTLET COUPLING
1-1/2" S.J. RUBBER
1-1/2" FRICTION RING
1-1/2" S.J. RUBBER

54.207

Figure 2-18.—Piston type of flushing valve.

valve tilts open. Then pressure decreases in the upper chamber to less than that of the incoming and flushing water. The action allows the flushing water pressure to raise the diaphragm off the flushing seat and recycle.

Figure 2-18 shows a piston type of flushing valve. With this type of flush valve, the piston is drawn up when the flushing begins then to its closed position by the filling of the upper chamber through the expeller orifice tube.

Flush valve assemblies on urinals and water closets may be protected from unnecessary damage and wear by installing a grip handle or guard firmly over the handle housing. (See fig. 2-19.) This grip handle increases the operating life of flush valves and thereby reduces service calls on the repair of flush valve assemblies and plumbing fixtures.

SINKS

Sinks are made in different patterns, each intended to serve a specific purpose. Two common types of sinks are the kitchen sink and the slop sink.

The KITCHEN sink is available in different sizes and may have either a single bowl or a double bowl. It is made of stainless steel, enameled steel, or enameled cast iron.

In the installation of a kitchen sink, it is important that the sink be built into a cabinet or hung from a bracket that is screwed to a mounting board. (See fig. 2-3.) The bracket should be screwed into the mounting board in a position where the sink, when mounted, is at a convenient height for use. As a rule of thumb, the distance between the top of the drainboard and finished floor should not be less than 36 inches.

After screwing the bracket into place, lower the sink into position on the bracket so the lugs cast into the back of the sink fit down into the corresponding notches in the bracket. Screw the strainer and tailpiece into the sink bowl and connect the trap to the rough-in waste. To complete the installation, select a suitable faucet. Install the faucet on the sink and connect the

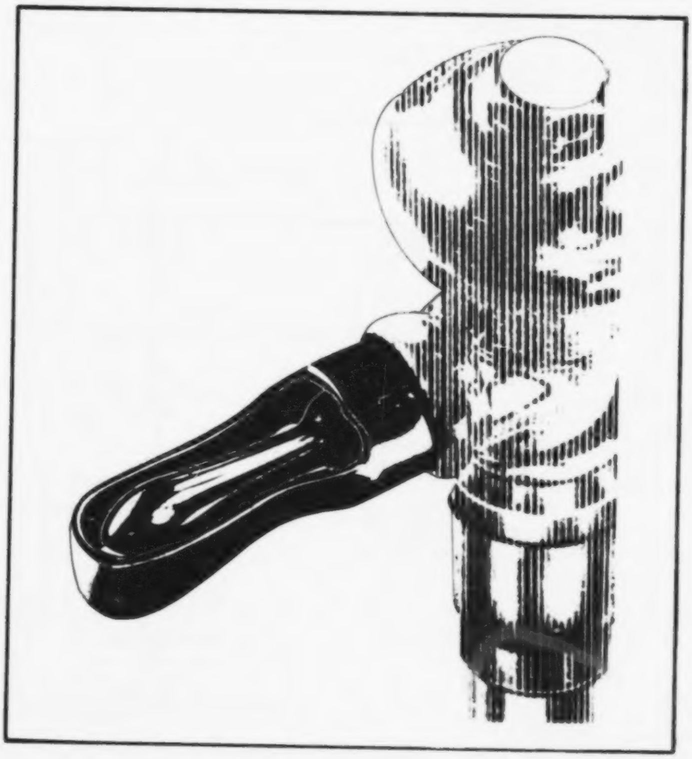


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Figure 2-19.—Flushing valve guard.

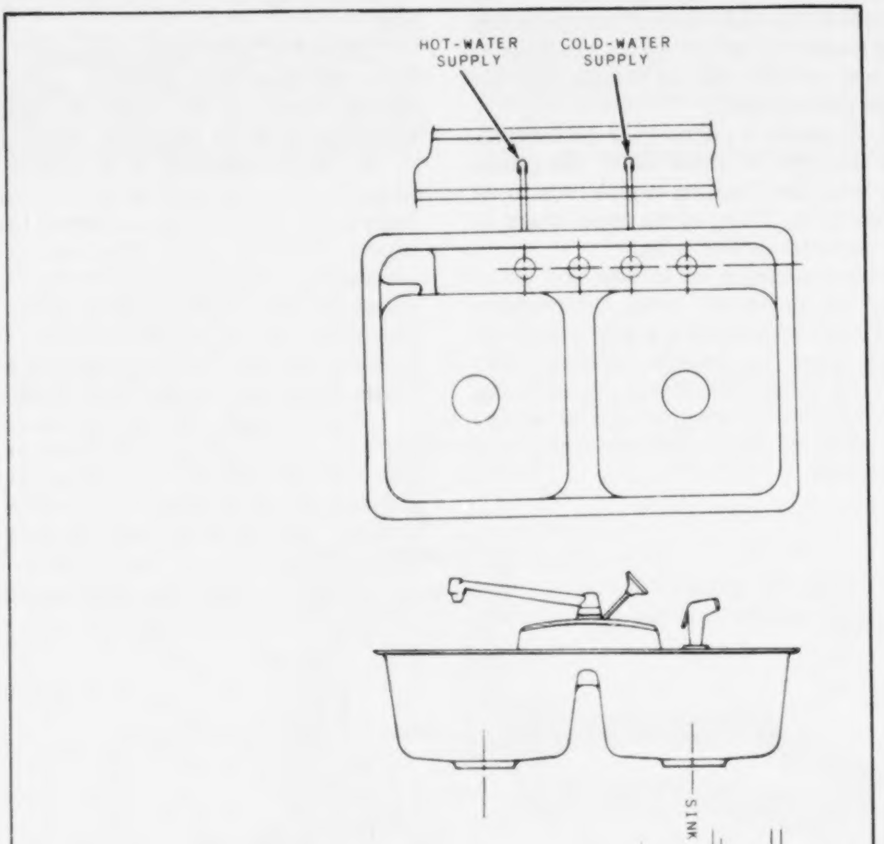

HOT-WATER SUPPLY
COLD-WATER SUPPLY
SINK FITTING
1/2" COPPER PIPE
1/2" COPPER 90° ELL
1/2" COPPER PIPE
1/2" ESCUTCHEON
ANGLE SHOP 3/8" O.D. COMPRESSION x 1/2" COPPER PIPE FEMALE
NOTE:
ADAPTER FITTINGS CAN BE
3/8" COMPRESSION x 3/8" COMPRESSION
3/8" COMPRESSION x 1/2" COMPRESSION
3/8" COMPRESSION x 1/2" IPs.

Figure 2-20.—Kitchen sink water-supply hookup.

water supply to it, as shown if figure 2-20. Then install and connect the waste lines to the sink, as shown in figure 2-21.

A SLOP sink, also referred to as a SERVICE sink, is especially useful for washing with a bucket and swab. It has a deep bowl and generally is constructed of cast iron and finished in enamel.

The slop sink installation is similar to the kitchen sink installation. The slop sink is also mounted on a bracket and mounting board. (See fig. 2-4.) In addition to the hanger, the slop sink has a built-in adjustable stand trap that bolts to the floor and provides pedestal support (fig. 2-22). The stand trap should be adjusted to take most of the weight off the hanger and prevent the unit from sagging. After the fixture has been set in place and the waste supply has been connected, suitable faucets are installed and connected to the water supply, and the unit is ready for use.

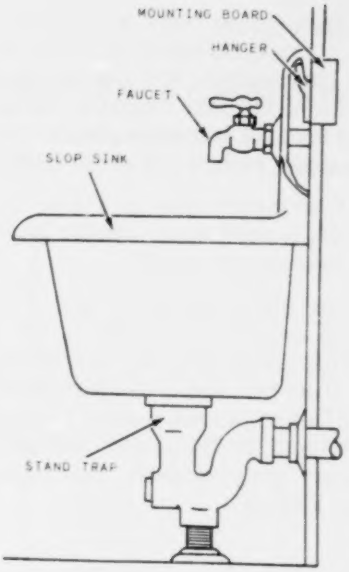

MOUNTING BOARD
HANGER
FAUCET
SLOP SINK
STAND TRAP

Figure 2-22.—Detail of a slop (service) sink.

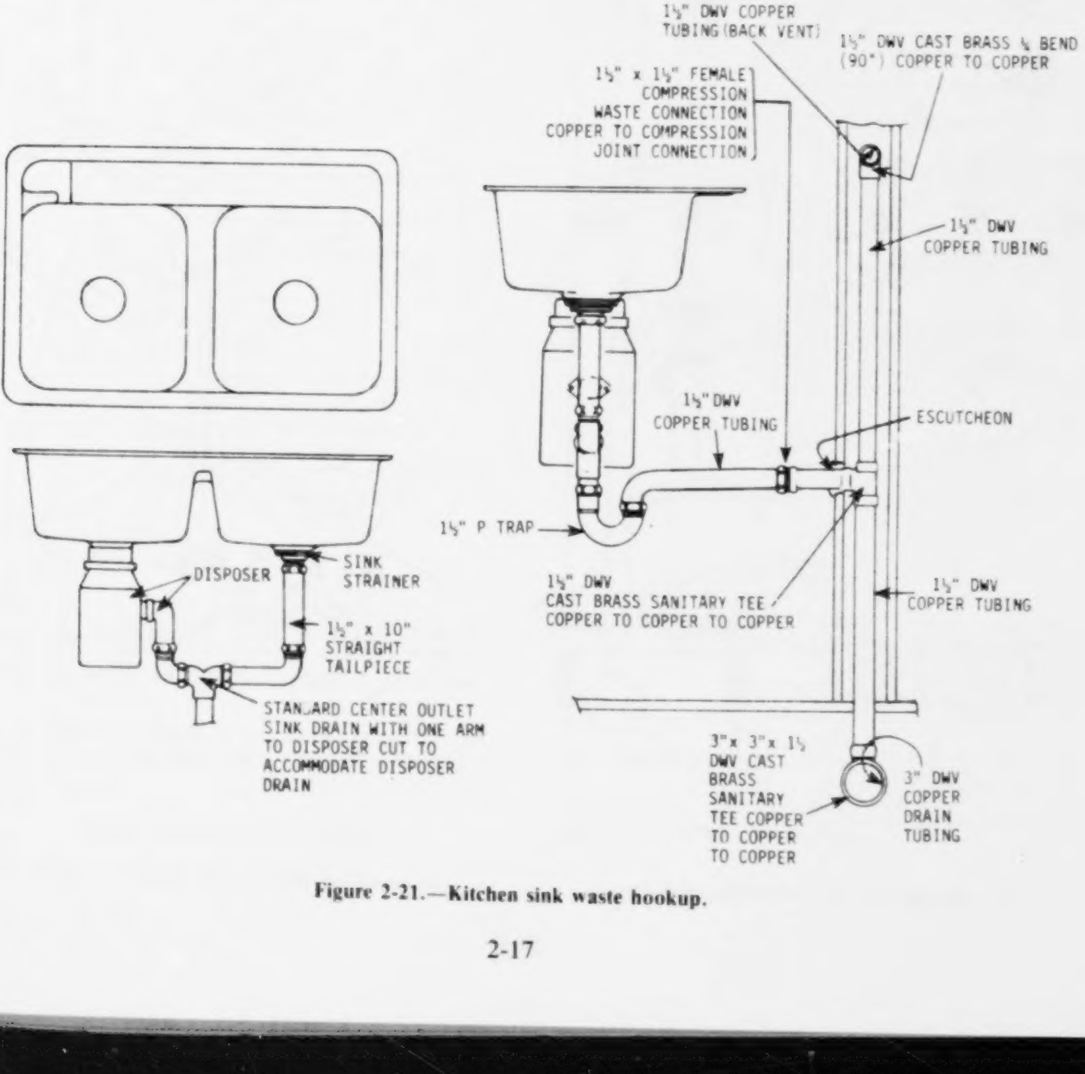

DISPOSER
SINK STRAINER
1½" x 10" STRAIGHT TAILPIECE
STANDARD CENTER OUTLET SINK DRAIN WITH ONE ARM TO DISPOSER CUT TO ACCOMMODATE DISPOSER DRAIN
1½" DWV COPPER TUBING (BACK VENT)
1½" DWV CAST BRASS ¼ BEND (90°) COPPER TO COPPER
1½" x 1½" FEMALE COMPRESSION WASTE CONNECTION COPPER TO COMPRESSION JOINT CONNECTION
1½" DWV COPPER TUBING
1½" DWV COPPER TUBING
ESCUTCHEON
1½" P TRAP
1½" DWV CAST BRASS SANITARY TEE COPPER TO COPPER TO COPPER
1½" DWV COPPER TUBING
3" x 3" x 1½ DWV CAST BRASS SANITARY TEE COPPER TO COPPER TO COPPER
3" DWV COPPER DRAIN TUBING

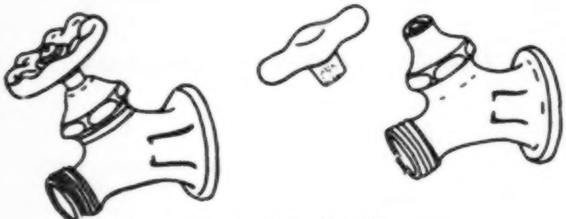
Figure 2-21.—Kitchen sink waste hookup.

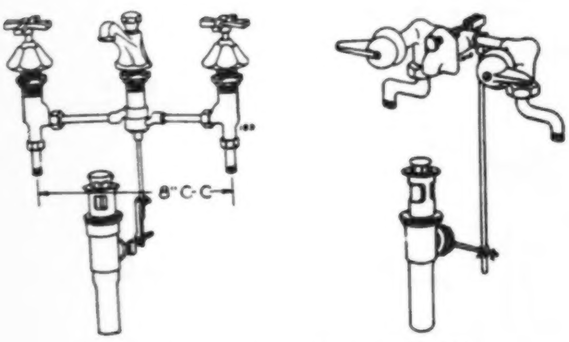
FAUCETS

As a Utilitiesman, you may often be called upon to install or make repairs to faucets. There are many types of faucets in general use, such as bibb, lavatory, bath, and kitchen combinations.

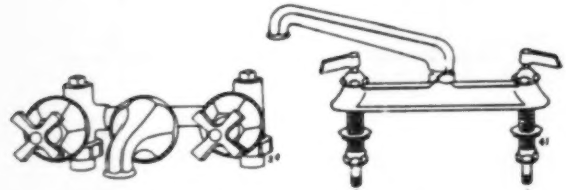
The hose bibb faucet, as shown in view A, figure 2-23, is used where outside hose connections to faucets are needed.

You probably recognize the combination faucets, as shown in views B, C, and D of the figure. This faucet generally is used to combine the flow from hot- and cold-water pipes. A main feature of these faucets enables the water to be tempered as it is discharged through a single spout. They are commonly used in lavatories, baths, or kitchens.


A. HOSE BIBB



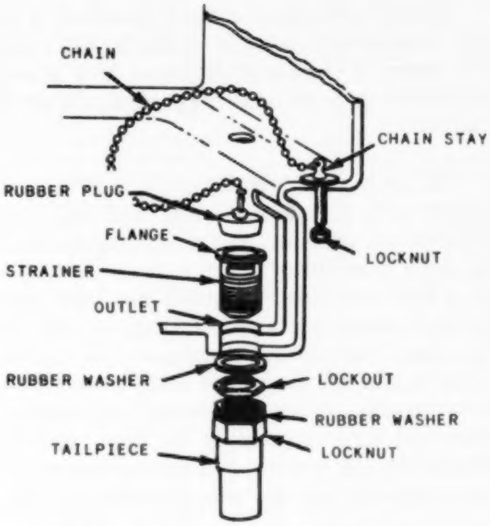
B. LAVATORY COMBINATION



C. BATH COMBINATION

D. KITCHEN COMBINATION

Figure 2-23.—Types of faucets.


CHAIN
CHAIN STAY
RUBBER PLUG
LOCKNUT
FLANGE
STRAINER
OUTLET
RUBBER WASHER
LOCKOUT
RUBBER WASHER
TAILPIECE
LOCKNUT
A. EXPLODED VIEW OF A P.O. PLUG DRAIN

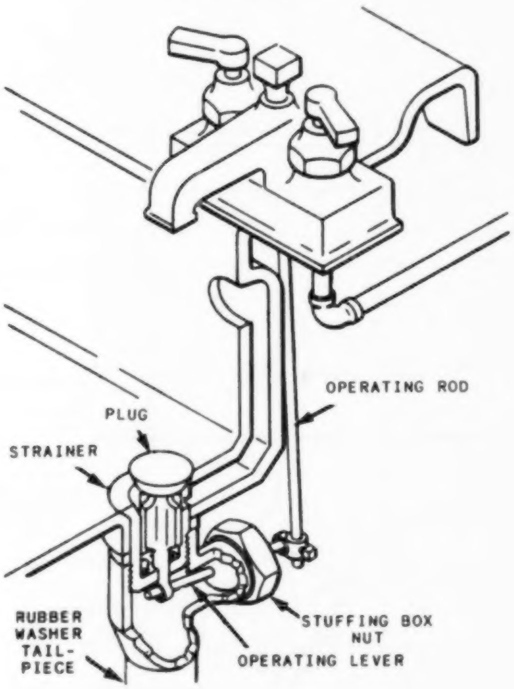

OPERATING ROD
PLUG
STRAINER
RUBBER WASHER
TAIL-PIECE
STUFFING BOX NUT
OPERATING LEVER
B. CUTAWAY VIEW OF A COMBINATION LAVATORY FAUCET AND POP-UP DRAIN

Figure 2-24.—Lavatory drains.

LAVATORIES

The wall-hung lavatory, the most common type in use, is suspended from a bracket screwed to the wall. It may or may not be supported (additionally) by legs. Figure 2-5 shows a view of a wall-hung lavatory. To install this fixture, follow the steps below in the order given.

1. Mark the wall at the correct height for a lavatory and secure the hanger to the wall.
2. Position the lavatory on the hanger.
3. Install the lavatory faucets using a basin wrench.
4. Install the permanent opening (P. O.) plug drain, as shown in view A, figure 2-24, or the pop-up type of drain, as shown in view B, figure 2-24.
5. Connect the water-supply lines, as shown in figure 2-25, to the faucets.

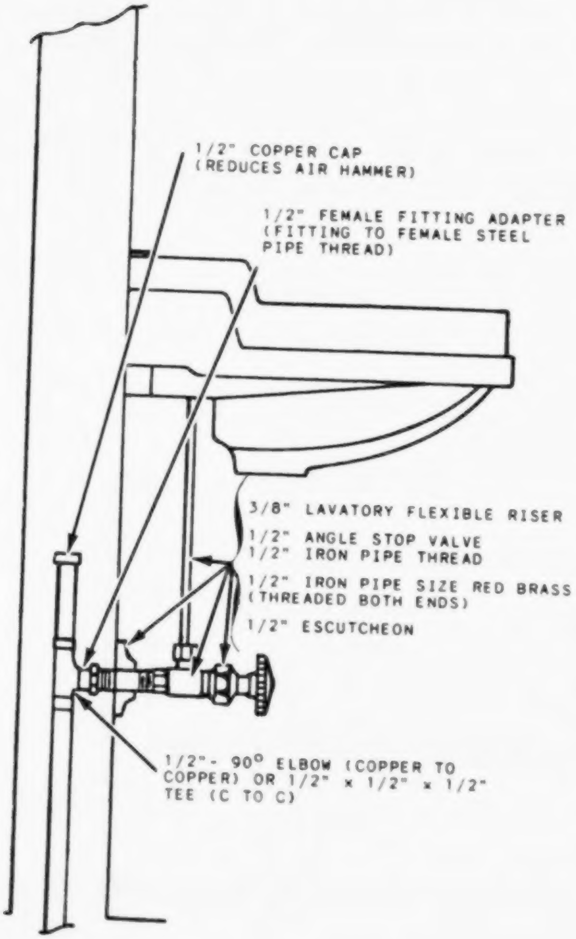

1/2" COPPER CAP (REDUCES AIR HAMMER)
1/2" FEMALE FITTING ADAPTER (FITTING TO FEMALE STEEL PIPE THREAD)
3/8" LAVATORY FLEXIBLE RISER
1/2" ANGLE STOP VALVE
1/2" IRON PIPE THREAD
1/2" IRON PIPE SIZE RED BRASS (THREADED BOTH ENDS)
1/2" ESCUTCHEON
1/2"- 90° ELBOW (COPPER TO COPPER) OR 1/2" x 1/2" x 1/2" TEE (C TO C)

Figure 2-25.—Lavatory water-supply lines hookup.

6. Connect the waste supply lines, as shown in figure 2-26, to the lavatory.

SHOWER AND TUB COMBINATION

Several types of bathtubs are on the market today. Some of them are the recessed, corner

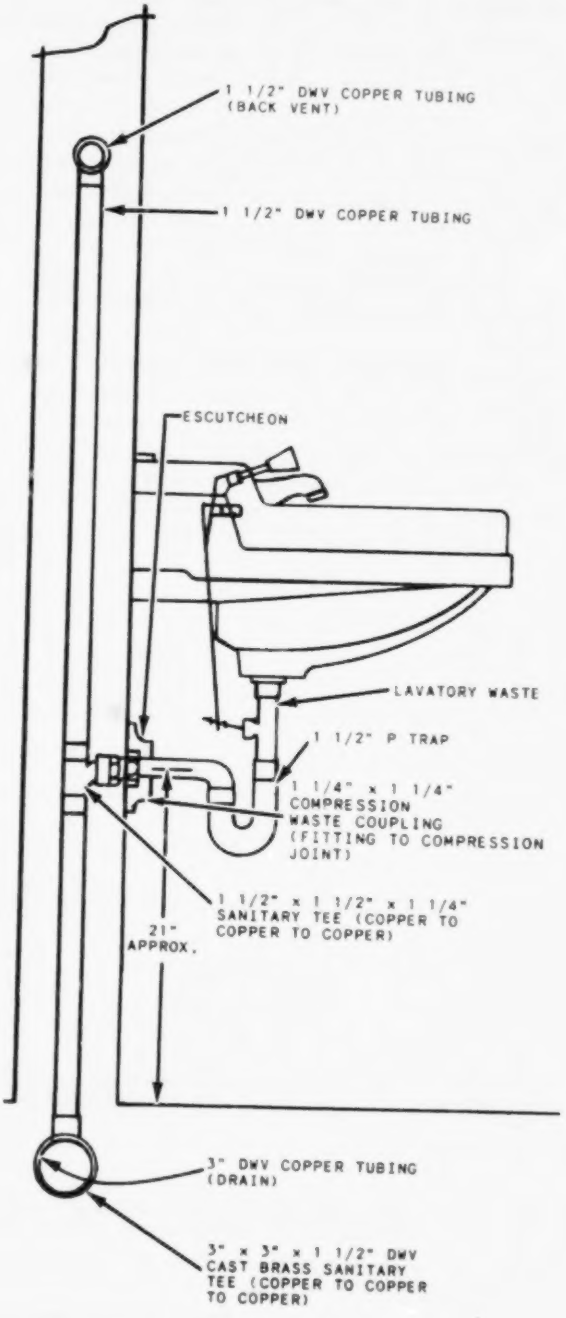

1 1/2" DWV COPPER TUBING (BACK VENT)
1 1/2" DWV COPPER TUBING
ESCUTCHEON
LAVATORY WASTE
1 1/2" P TRAP
1 1/4" x 1 1/4" COMPRESSION WASTE COUPLING (FITTING TO COMPRESSION JOINT)
1 1/2" x 1 1/2" x 1 1/4" SANITARY TEE (COPPER TO COPPER TO COPPER)
21" APPROX.
3" DWV COPPER TUBING (DRAIN)
3" x 3" x 1 1/2" DWV CAST BRASS SANITARY TEE (COPPER TO COPPER TO COPPER)

Figure 2-26.—Lavatory waste supply hookup.

recessed, sunken, and leg type. Most tubs are made in several sizes ranging from 4 to 6 feet in length and are designed as right- or left-hand tubs, depending on the location of the drain. When you face the tub, if the drain is on the right end, it is a right-hand tub; if on the left end, a left-hand tub. Most bathtubs today are made of enameled cast iron, enameled pressed steel, or the fiber glass design which is most commonly used for the built-in type.

The installation of both bathtub and shower is simple. Tubs and showers come in many different applications: tubs, showers, tub and shower combination, and "gang showers." The majority of your work will be installing gang showers in a large room with no privacy partitions or dividers.

To install a tub like the type shown in view A, figure 2-27, place the rim of the tub on the 2- by 4-inch support nailed to the 2- by 4-inch studs, as shown in view B, figure 2-27. Check to be sure the tub is level. Once the tub is in place,

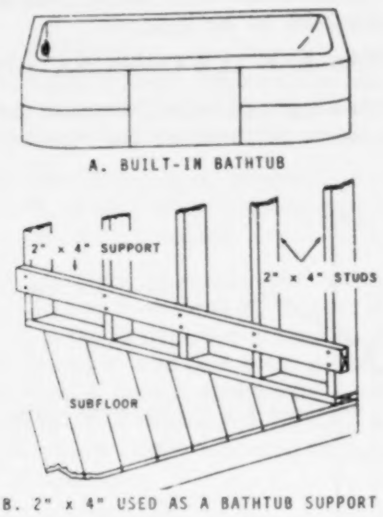

A. BUILT-IN BATHTUB
2" x 4" SUPPORT
2" x 4" STUDS
SUBFLOOR
B. 2" x 4" USED AS A BATHTUB SUPPORT

Figure 2-27.—Bathtub and support.

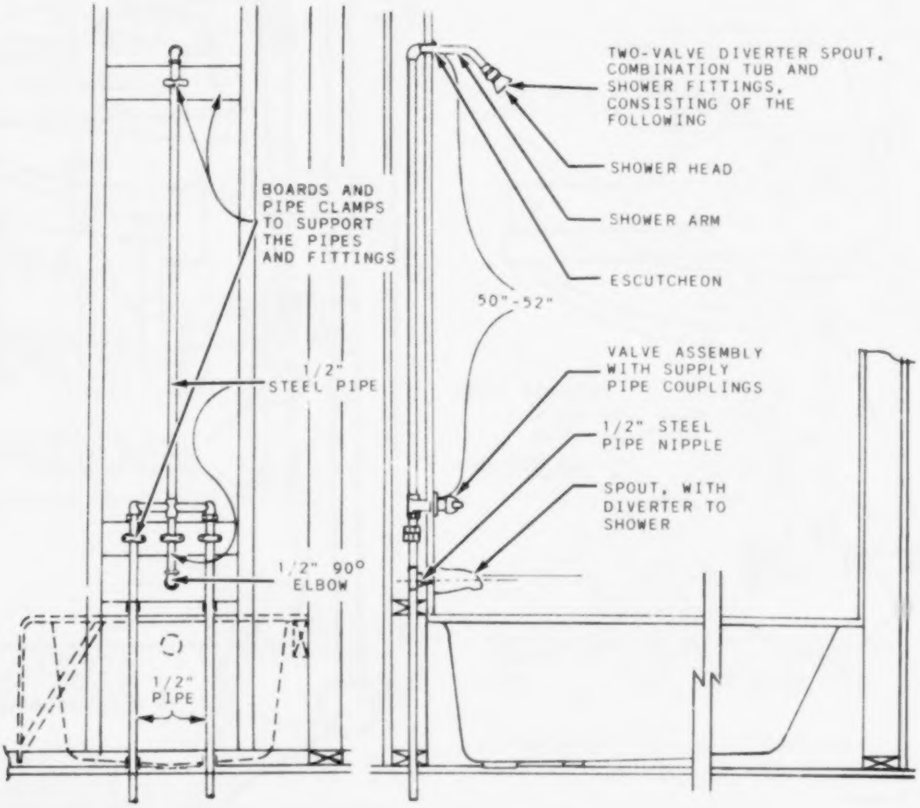

TWO-VALVE DIVERTER SPOUT, COMBINATION TUB AND SHOWER FITTINGS, CONSISTING OF THE FOLLOWING
SHOWER HEAD
SHOWER ARM
ESCUTCHEON
BOARDS AND PIPE CLAMPS TO SUPPORT THE PIPES AND FITTINGS
50"-52"
VALVE ASSEMBLY WITH SUPPLY PIPE COUPLINGS
1/2" STEEL PIPE
1/2" STEEL PIPE NIPPLE
SPOUT, WITH DIVERTER TO SHOWER
1/2" 90° ELBOW
1/2" PIPE

Figure 2-28.—Bathtub and shower piping combination.

hook up the water-supply lines, as shown in figure 2-28. Now, you have a bathtub and shower combination. Water is furnished by a faucet and spray nozzle. Two valves usually control the flow of water to these units. Ordinarily, when the valves are opened, the water runs into the bathtub from the bathtub faucet. However, for water to run through the shower head, the valves must be opened and the diverter, which is also located in the bathtub, raised. This combination gives the bather a choice of taking a bath or taking a shower.

A tub drain and overflow are usually similar to that shown in figure 2-29. The drain assembly is installed in the space provided by the studs at the end of the tub. The overflow and waste drain are made of chrome. The hidden parts are of rough brass and brass tubing. The fittings are 1 1/2 inches in diameter and come with a pop-up waste or rubber stopper fastened to the overflow by a chrome chain. This drain and overflow combination is connected to the P trap with slip-joint nuts and rubber washers to seal off the leaks. The drain in the bottom of the tub is sealed against leaks with plumber's putty and rubber rings.

The wastewater supply lines, as shown in figure 2-30, are then connected to the tub.

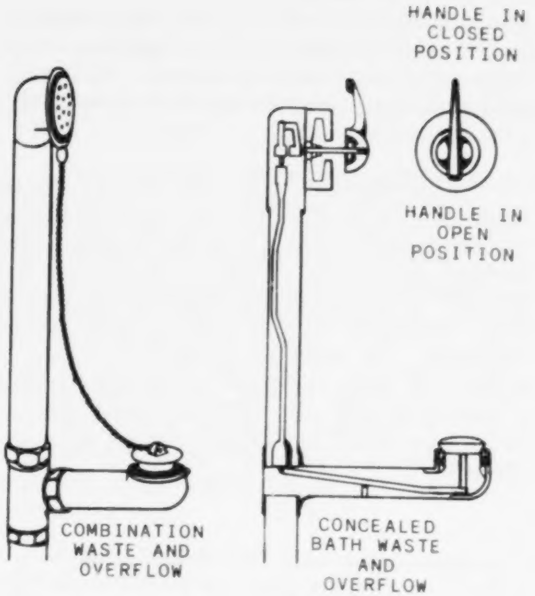

HANDLE IN CLOSED POSITION
HANDLE IN OPEN POSITION
COMBINATION WASTE AND OVERFLOW
CONCEALED BATH WASTE AND OVERFLOW

Figure 2-29.—Bathtub combination waste and overflow.

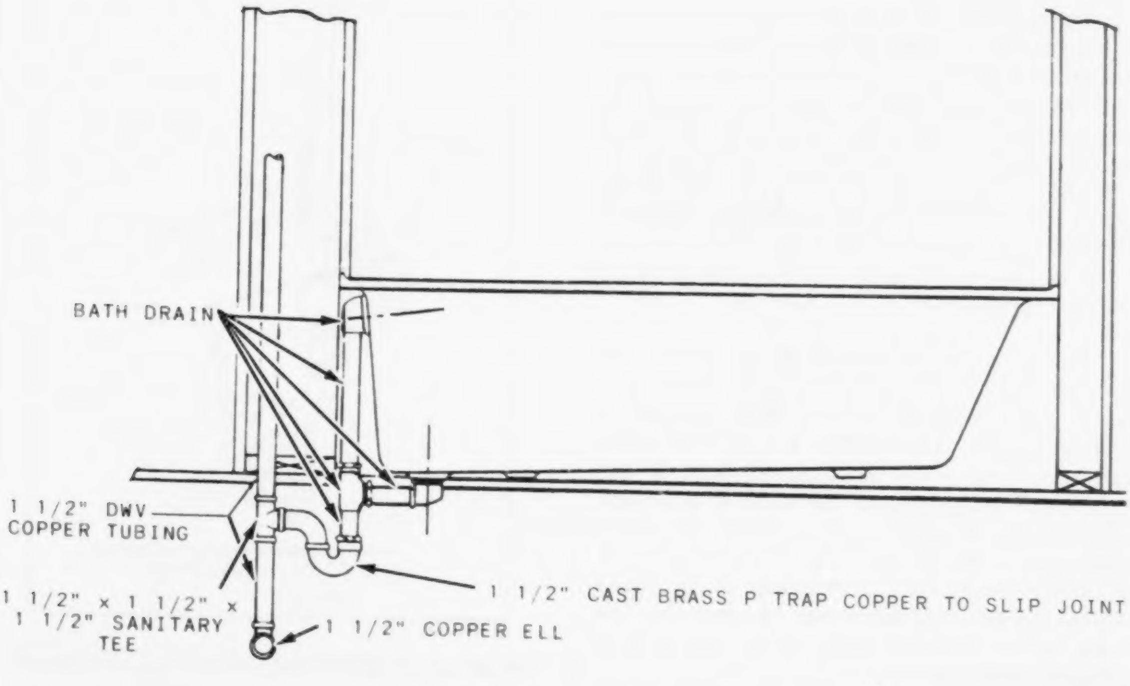

BATH DRAIN
1 1/2" DWV COPPER TUBING
1 1/2" x 1 1/2" x 1 1/2" SANITARY TEE
1 1/2" COPPER ELL
1 1/2" CAST BRASS P TRAP COPPER TO SLIP JOINT

Figure 2-30.—Tub waste supply hookup.

The faucet and shower combination for a bathtub and shower is connected to the hot and cold waterlines that were installed when the piping was roughed-in. The manufacturer's specifications should be used to determine the height of the riser. The height, however, may be specified by the user. The shower and bathtub piping and fittings, installed within the wall, are made of rough brass; those that extend through the finished wall have a chrome finish. A typical bathtub and shower piping arrangement is shown in figure 2-31. When you make this type of bathtub and shower installation, be sure to locate the bathtub spout from 2 to 4 inches above the rim of the tub. Spacing the spout above the rim of the tub prevents siphoning of the water from the tub in case the valve is left open and the water drops at the same time. This installation prevents cross-connection between potable and nonpotable water.

The mixing valves in the shower system supply a uniform temperature of water for the shower or tub. The temperature of the water may be regulated between the limits of the temperature of the cold-water supply and the hot-water supply. The types of mixing valves used to control the water temperature are manual, pressure, or thermostatic.

The manually controlled mixing valves consist of two hand-operated valves in one body with an outlet for both valves that feed the shower head. The valves are turned by hand to control the temperature of the water. Manually controlled valves require a piping arrangement similar to the one shown in figure 2-32. This water tempering setup does not protect against sudden changes in temperatures due to slugs of hot or cold water from varying pressures or from water temperature in the supply lines.

The pressure-controlled mixing valve, like the one shown in view A, figure 2-32, consists of a brass mixing chamber that contains a sliding piston. The piston has jets to allow hot and cold water to pass through it and mix when the handle of the valve is operated. The setting of the handle controls the water temperature by establishing the mixing ratio. A change in pressure on one side of the piston causes the piston to move and increase the flow from the low-pressure supply to maintain a nearly constant pressure.

The thermostatically controlled mixing valve, similar to the one shown in view B, figure 2-32, is sensitive to changes in both temperature and pressure. The temperature of the water delivered by the valve remains constant regardless of the temperature and pressure changes in the hot and cold waterlines. The thermostatic mixing valve is used for showers only.

The shower head is attached to a 45° fitting mounted on a chrome pipe. There are two general types of shower heads: circular and economy. The circular spray head shown in figure 2-33 has notches or grooves around the outer edge of its face. The spray in this type of head can be regulated. The economy head, also shown in figure 2-33, has a restricted nozzle that provides a finer spray and uses less water. Both showers heads have a ball-and-socket joint for adjusting direction of the spray.

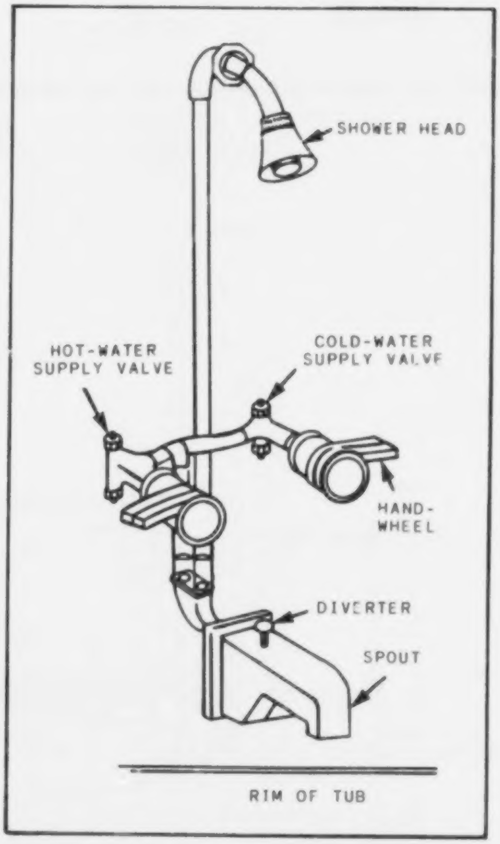


Figure 2-31.—Bathtub and shower piping arrangement.

Shower heads are usually made of chrome- or nickel-plated brass. Newer types of shower heads are made of noncorrosive plastic. Deposits tend to form on the shower head because of the chemical content of the water. Therefore, occasional maintenance is required to keep them functioning properly.

The most important requirement in a shower installation is the absolute waterproofing of walls and floors. Walls are less of a problem than floors since they are subject only to splashing of water and do not have water standing or collecting on them. Careful installation of tile or other impervious material with waterproof cement generally suffices to provide a waterproof wall installation. In the installation of the floor, an impervious waterproof subbase must be put under the shower floor, or water standing on the floor will gradually seep through and cause leaks.

Concrete shower pans used with prefabricated steel shower stalls are relatively easy to install. In many cases, steel shower stalls are set up after the original construction. In this case, the cement base is usually not recessed into the floor but is laid directly on top of the floor.

More and more steel fabricated shower stalls are being replaced with fiber glass. Both units are installed in the same manner. The finished interior of a shower stall should be at least 30 inches. The shower head should be a minimum of 68 inches

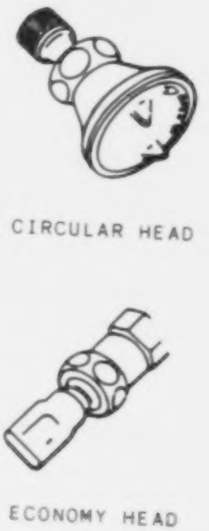
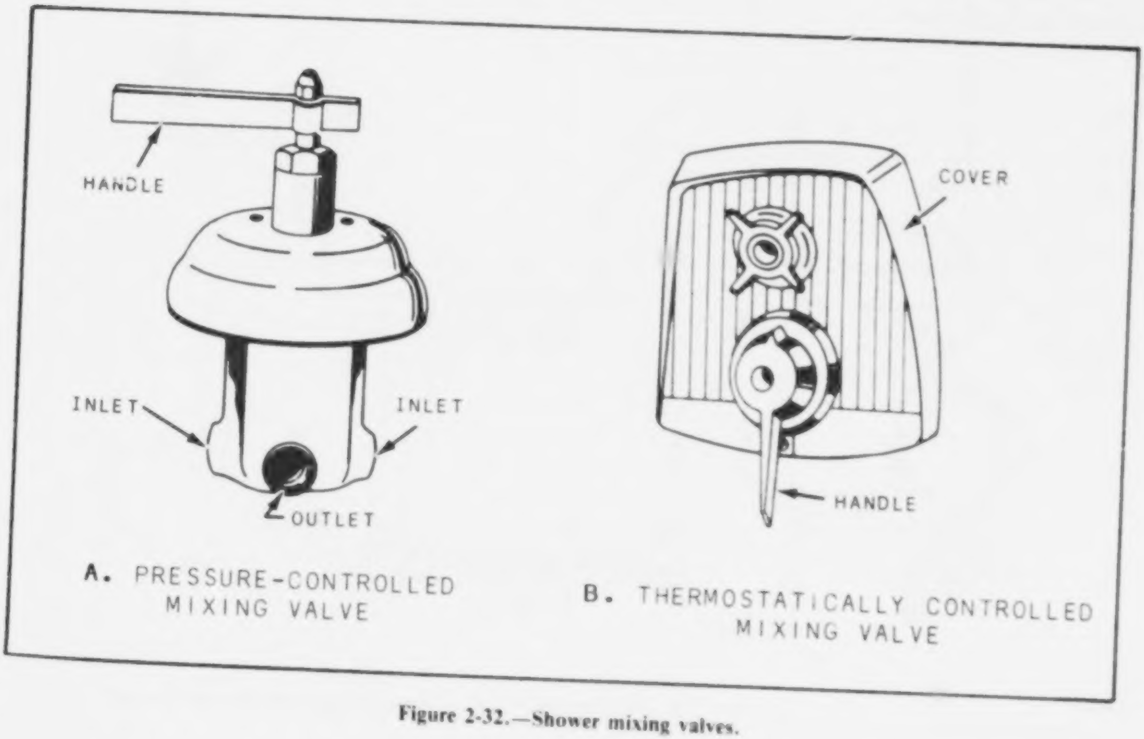


Figure 2-33.—Types of shower heads.



A. PRESSURE-CONTROLLED MIXING VALVE

B. THERMOSTATICALLY CONTROLLED MIXING VALVE

Figure 2-32.—Shower mixing valves.

above the level of the drain on the shower pan (fig. 2-34). Figure 2-35 shows a cutaway view of a shower pan. All seams should be caulked to prevent leaking, and all pipe openings in the wall of the stall should be sealed. Be sure to follow the manufacturer's instructions that accompany the fixtures and trim. In connecting, the shower pan is connected to a P trap following the manufacturer's instructions that accompany the shower pan.

URINALS

Two major types of urinals in use are the floor-mounted and wall-mounted urinals. In the remainder of this section only the main items relating to installation of a wall-hung urinal are considered. (See fig. 2-36.) If you learn to install this type of urinal, you should have little trouble installing a floor-mounted urinal.

In setting a wall-mounted urinal, see that the rough-in of the waste pipe is at the correct height so after installation the urinal is within reach of the user. The lip of the urinal should be from 20 to 25 inches from the floor. If the rough-in already installed in the building places the height of the urinal above or below these general measurements, the rough-in should be removed and the waste pipe brought in at the proper height. Since the wall-hung urinal sometimes has an integral trap, it is not always necessary to provide the waste pipe with a separate chrome or iron trap. Where the urinal is to hang on the wall by screws, a mounting board must be installed to provide firm support for the urinal. The last step in the installation of the wall-hung urinal is the

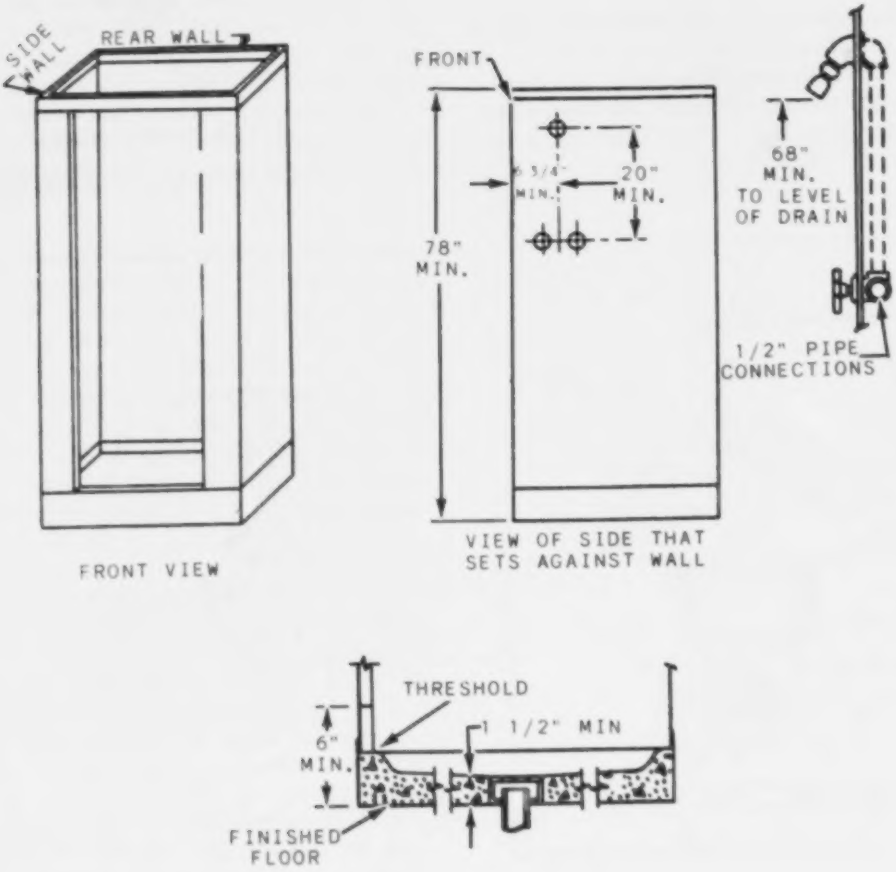

SIDE WALL
REAR WALL
FRONT VIEW
FRONT
6 3/4" MIN.
20" MIN.
78" MIN.
VIEW OF SIDE THAT SETS AGAINST WALL
68" MIN. TO LEVEL OF DRAIN
1/2" PIPE CONNECTIONS
THRESHOLD
1 1/2" MIN
6" MIN.
FINISHED FLOOR

Figure 2-34.—Shower stalls and sections.

connection of a flushing mechanism, such as the diaphragm type of urinal flushing valve.

DRINKING FOUNTAINS

All types of drinking fountains should be installed with the orifice located from 30 to 40 inches above the floor, depending upon the general height of the users. One type of wall-mounted drinking fountain is shown in figure 2-37. The mounting of this fixture should be sturdy and strong enough to hold more weight than that of the fixture itself. Most drinking fountains must be installed with a 1 1/4-inch P trap underneath the waste, but a few are available with integral traps. The electrically cooled drinking fountain requires an electrical outlet nearby for power. Because of the many variations in style of drinking fountains, the manufacturer's installation procedures and specifications should be followed in each case.

GALLEY EQUIPMENT

Galley equipment must be installed in a safe, sanitary, and economical way. When new equipment is received, it must be unpacked, assembled for installation, and inspected carefully, checking to see that all parts are present and undamaged. Follow the manufacturer's instructions for assembling the equipment.

Because of the differences in types of equipment you will be installing, only general information is presented here. Remember, the manufacturer's manual should be studied

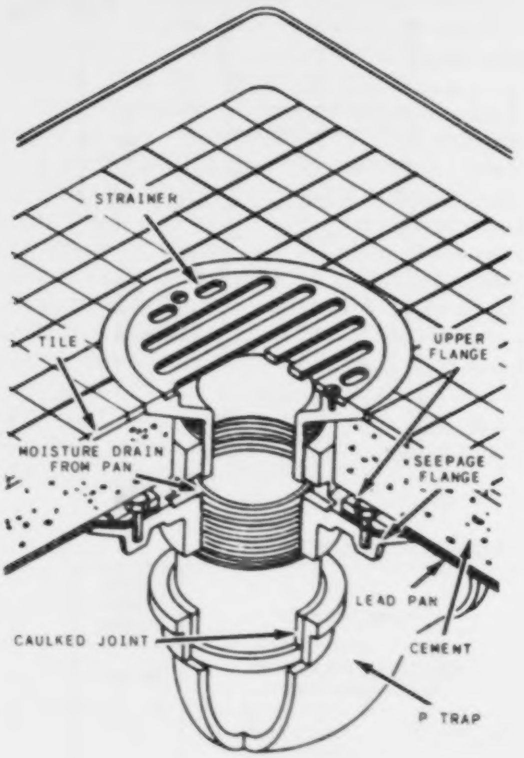


Figure 2-35.—Cutaway view of a shower pan drain.

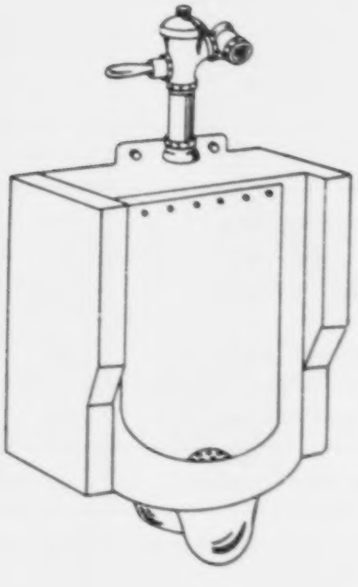


Figure 2-36.—Wall-mounted urinal.

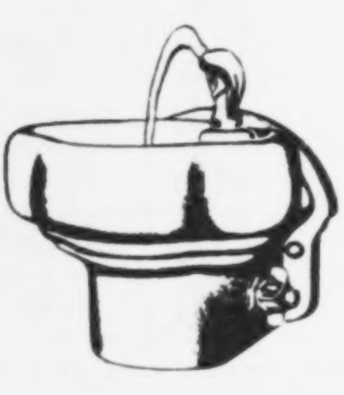


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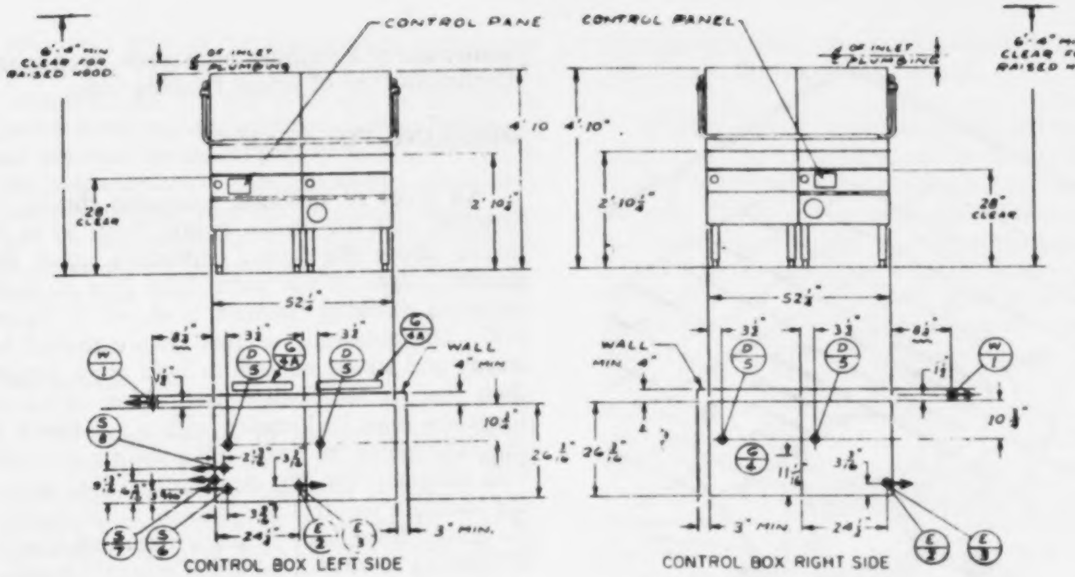
Figure 2-37.—Wall-mounted drinking fountain.


CONTROL PANE
6'-4" MIN CLEAR FOR RAISED HOOD
OF INLET PLUMBING
4' 10
2' 10¾"
28" CLEAR
52¼"
8½"
3½"
3½"
W/1
D/5
G/4A
G/4A
D/5
WALL 4" MIN
S/8
10¼"
26 1/16"
3 1/16"
3" MIN.
24½"
S/7
S/6
E/2
E/3
CONTROL PANEL
4'10"
2' 10¾"
28" CLEAR
6'-4" MIN CLEAR FOR RAISED HOOD
OF INLET PLUMBING
52¼"
WALL MIN 4"
3½"
3½"
8½"
W/1
D/5
D/5
1½"
10¼"
26 1/16"
26 1/16"
G/4
11 1/16"
3 1/16"
3" MIN
24½"
E/2
E/3

CONTROL BOX LEFT SIDE

CONTROL BOX RIGHT SIDE

SERVICE CONNECTION INFORMATION

MK. NO.	SERVICE CONNECTION	FITT.	FUNCTION	DIM. FROM FLOOR
W/1	180° MIN.	1"	TANKS FILL INLET AND FINAL RINSE INLET	60-1/4"
E/2	ELECTRIC 30 AMPS 15 AMPS 8 AMPS 7.2 AMP 3.6 AMPS	1-1/8"	CONTROL PANEL AND 2 MOTORS 115/60/1 230/60/1 208/60/3 230/60/3 460/60/3	25"
E/3	ELECTRIC 24 AMPS 26 AMPS 24 AMPS 11.4 AMPS	1-1/8"	2 TANK HEATERS - TOTAL 5.0 KW 230/60/1 208/60/3 230/60/3 460/60/3	25"
4	GAS INLET	1/2" NPT FEM.	GAS TANK HEAT	10-1/4"
G/4A	GPS FLUE	19-3/4"	GPS BURNER VENT	16"
D/5	(2) DRAINS	2"	CONNECTS TO WASTE	12-1/2"
S/6	STEAM	3/4"	TANK HEAT - INJECTOR	10"
S/7	STEAM	3/4"	TANK HEAT - COIL-IN	10"
S/8	STEAM	3/4"	TANK HEAT - COIL-OUT	10"

TANKS REQUIRE 37.0 GAL OF HOT WATER TO FILL. FINAL RINSE REQUIRES MAX. OF 260 GAL PER HOUR OF 140° HOT WATER.

TOTAL STEAM REQUIREMENT 50 LBS COND./HR AT 20 PSI

Figure 2-38.—Rough-in information.

carefully before you install a new piece of equipment. The manual also provides the rough-in information you need to install the equipment properly. (See fig. 2-38.)

The installation of food preparation equipment may vary. In peacetime, most all types are in a permanent galley or bakeshop. While operating in a construction battalion deployed for construction and/or training to an island or an overseas shore station, the battalion might have either a permanent galley or a semipermanent galley, using either field units or fixed-type equipment. In a disaster—hurricane, flood, or fire—Seabees may be called upon to help. In such cases, field units—of the same type used in combat zones—are used for preparing food. The major features of common types of galley equipment are provided in the subsections that follow.

COPPERS

Steam-jacketed kettles are referred to as COPPERS by Mess Management Specialists in the Navy. A point to note, however, is that they are constructed of corrosion-resistant steel, aluminum, or single-clad corrosion-resistant steel (not copper). Coppers vary in size from 20 to 80 gallons and are used for boiling food without direct contact between the steam and the food. A jacket around the lower part of the copper allows steam to circulate between the jacket and the inner shell, thus heating the contents. Figure 2-39 shows several coppers installed and ready for use.

A hinged lid helps prevent the escape of heat from the top of the copper, and it serves as a cover for the food. Coppers are fitted with drawoff

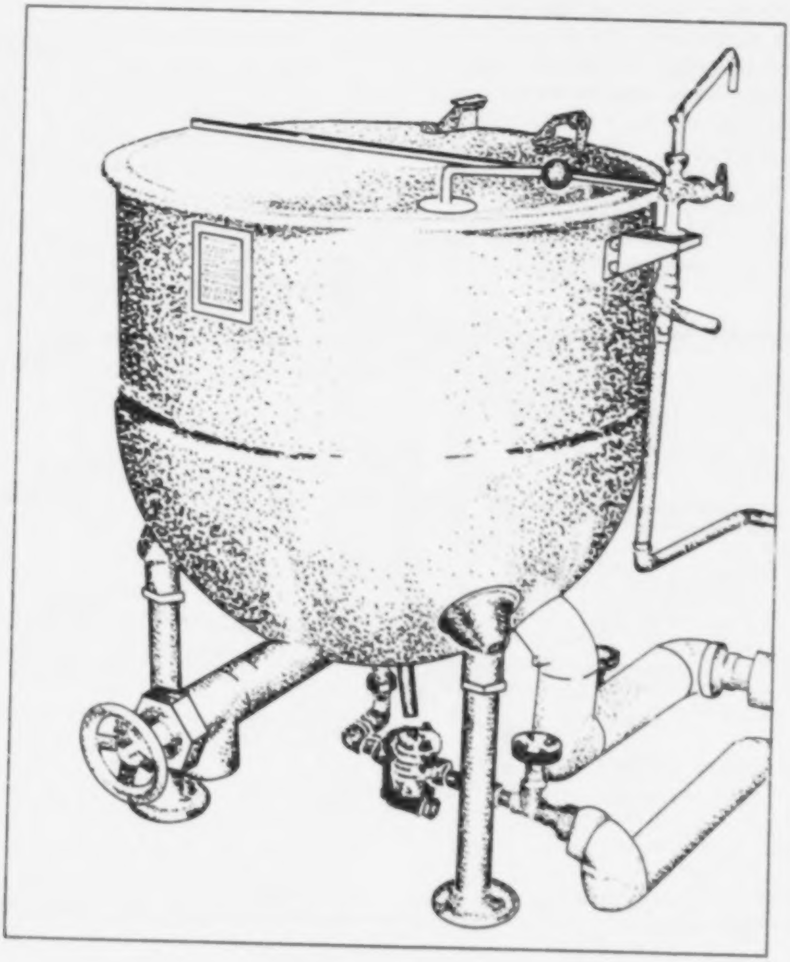


Figure 2-39.—Coppers.

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faucets, so the unit may also be used as a coffee urn. A special copper that can be tilted is often used in bakeries and galleys. With this type, the copper may be tilted to drain off liquids.

Coppers should be installed in a depressed floor area or behind a curb wall, if possible. The unit should be bolted securely to the floor. The steam supply piping should be the full size of the equipment inlet fitting, and the supply line should be fitted with a pressure-reducing valve. Also, a steam control valve should be placed near the copper for the convenience of the operator.

The steam supplied to coppers for service connections is reduced in pressure to approximately 40 pounds. Connect the condensate return line to the steam outlet connection. Then install a suitable steam trap in the condensate return line near the copper. In the cold-water supply line, install a globe valve and leave an air gap between the top of the copper and the water service line.

STEAM CHESTS

A steam chest, such as that installed in a modern Navy galley, is similar to a pressure cooker that is used in a private home. It is designed to cook food with live steam, under pressure, coming into direct contact with the food being prepared. (See fig. 2-40.) In a galley, the steam is supplied from an outside source. The steam is usually connected on the same line as the coppers. This is called a direct-connected chest or vegetable steamer and is the type most commonly used by the Navy.

When installing a direct-connected steam chest, place it in line or near the copper to make installation and cooking easier. Be sure the unit

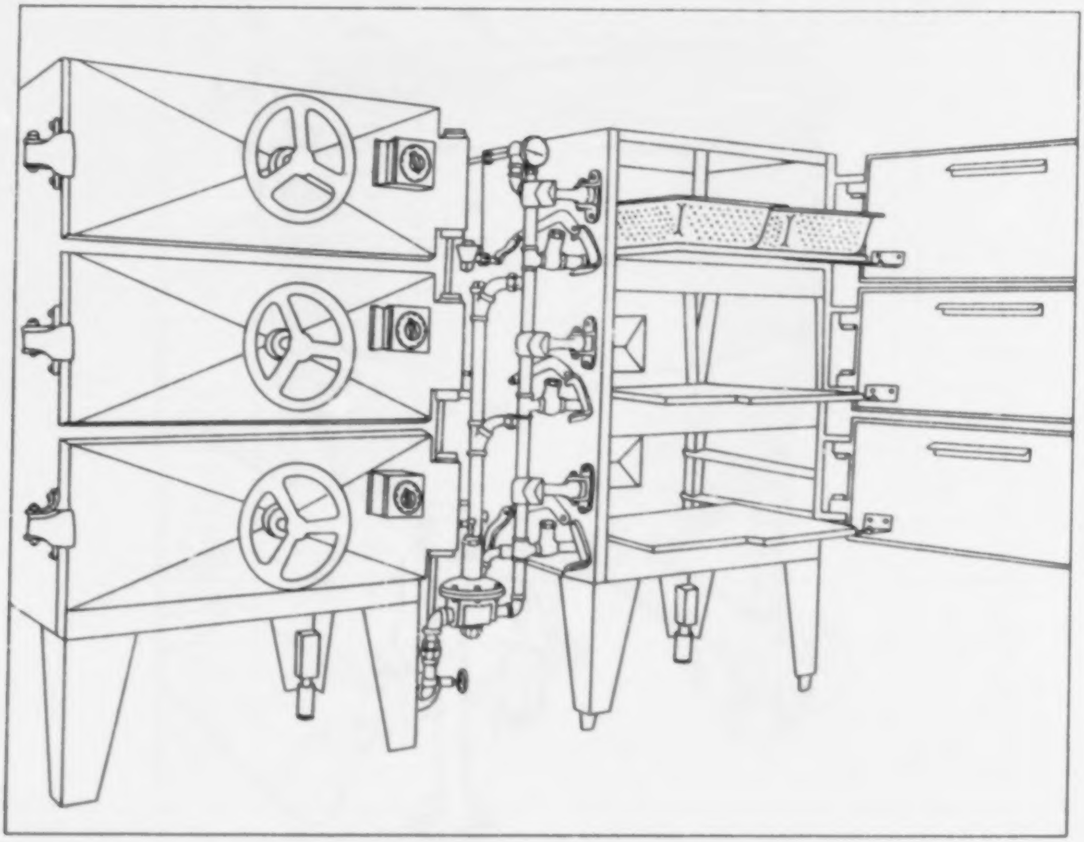

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Figure 2-40.—Steam chests.

is near a floor drain. This arrangement will permit compartment drips and drains to discharge without wetting the surrounding floor area.

Set the steam chest in a level position, using the adjusting bolts on the feet. As an aid to leveling, pour a small amount of water into one compartment and adjust the legs so water drains through the drain opening.

CAUTION: DO NOT MAKE A SOLID CONNECTION FROM THE BLOWOFF VALVE TO THE DRAIN PIPING.

When steam is connected to the steam chest, a pressure-reducing valve has to be installed to reduce the steam to about 7 pounds of pressure per square inch (psi) or less, as recommended by the manufacturer. For safe operation, set the safety valve to open just above the reduced pressure.

STEAM TABLES

Steam tables are placed along the food serving line. They are used to keep food brought from the kitchen area hot during the serving period. Steam tables may be equipped with various types of heating units, such as steam coils, electric elements, or gas burners. The steam-coil type is widely used by the Navy. Steam tables come in many different styles and sizes, but the construction is basically the same for all units. Figure 2-41 shows a schematic drawing of a typical steam table.

Steam tables are constructed of corrosion-resistant, light-gauge steel. The steam-heated type has a steam-coil inlet, control valve, and pressure-regulating valve on the inlet side. The outlet side is fitted with a strainer, bucket trap, check valve, and gate valve. Most steam tables are also fitted with a waterline to fill the water compartment.

Around the galley, you may often hear the term *bain-marie*. This item of equipment is used in the galley near the cooking units to keep cooked food warm, until it is needed on the serving line. Briefly stated, steam tables and bain-maries serve the same purpose.

When installing a steam table, place the unit on the floor in the desired area, making sure you have a level and firm foundation. Be sure the bottom of the water compartment slopes toward the drain outlet to enable complete drainage of water from the compartment when desired.

An indirect waste connection is required to discharge over a floor drain. Connect the water-supply line to the equipment connection. Connect the steam supply and condensate return line. Following the manufacturer's instructions, adjust controls to the prescribed temperature and pressure setting.

All steam and hot-water piping should be insulated whenever personnel face exposure to burns. Information on insulating is provided in chapter 3.

DISHWASHING MACHINES

Various types of dishwashing machines are used at Navy activities. Types that you may work

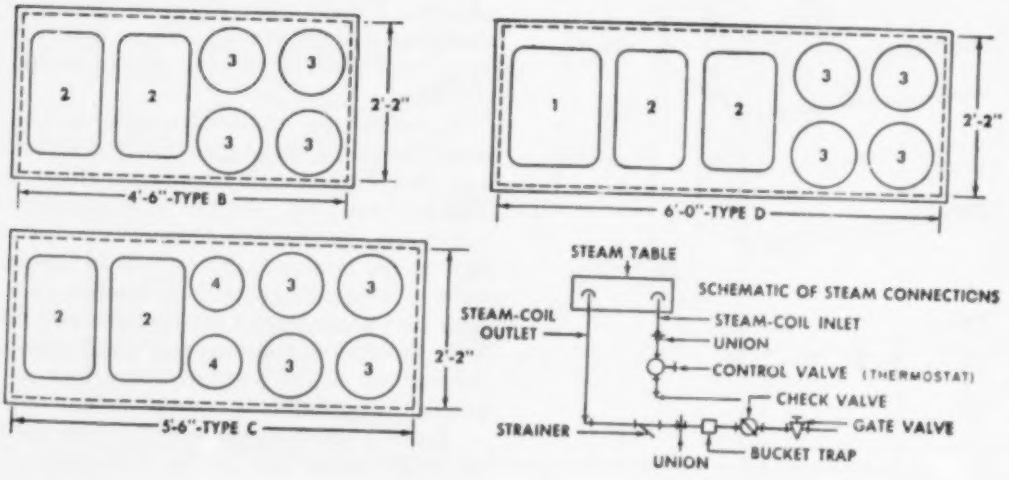

Figure 2-41.—Steam table.

with include the single-tank, multiple-tank, rackless, and domestic dishwashers.

Washing and rinsing are semiautomatic in a SINGLE-TANK unit. In ordinary single-tank units, a rack filled with dishes is placed in the machine by hand, and a lever regulates washing, spraying, and rinsing. Racks are removed by hand and replaced with other racks filled with dishes to be washed. A semiautomatic, single-tank dishwashing machine, which is suitable for small messes, is shown in figure 2-42.

In a MULTIPLE-TANK machine, dishwashing is automatic in that power wash spraying, power rinse spraying, and final rinsing may be carried on concurrently with two trays of dishes. A timing device is set to provide 20 seconds of washing and 10 seconds of rinsing. After a rack filled with soiled dishes has been washed, it slides automatically to the rinse compartment, in which water of at least 180 °F temperature is required. While the first rack of dishes is being rinse sprayed, the second rack of dishes is being washed. After a rack is pushed from the wash to the spray compartment, another rack of soiled dishes is placed by hand in the washing compartment. (See fig. 2-43.)

You may hear the RACKLESS type of dishwasher sometimes referred to as the FLIGHT type. These dishwashers are provided in single- and in multiple-tank units. The sequences of washing are much the same as in ordinary tank units, but the dishes are passed through the washing and rinsing compartment on a conveyor belt instead of in racks or trays. The loading section is on one side of the machine and the unloading section on the opposite side. An endless conveyor belt travels the entire length of the machine. The belts are usually made of stainless steel and nylon, and some belts have upright, nylon-covered pegs, which hold the dishes in place. The belt has an automatic stop mechanism to prevent damage to dishes or glasses if they are not removed before reaching the end of the unloading section of the machine. The belt is geared to move at a rate of speed which allows time for each dish or glass to be thoroughly washed and rinsed.

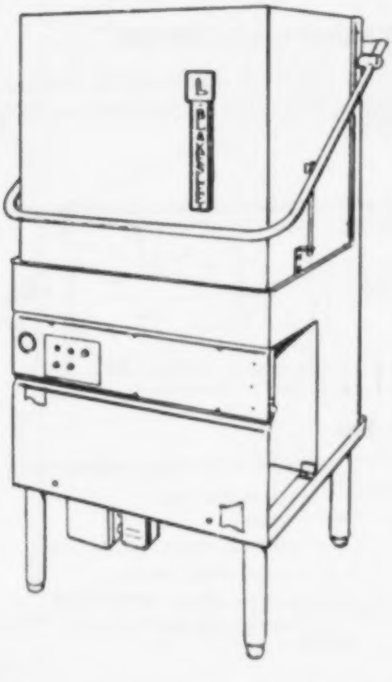

Figure 2-42.—Dishwashing machines, single-tank.

The DOMESTIC dishwasher comes as a separate unit or as part of a kitchen sink combination. It has features similar to those of a single-tank dishwasher. In most models, two racks filled with dishes are placed in the machine by hand, and its actions are controlled by the setting of a dial. This dial regulates the time for washing, spraying, and rinsing. Automatic dispensers control the supplies of detergent and wetting agents during the washing and rinsing cycles. Some models are equipped with safety interlock switches, which automatically shut off the current and stop all actions if the door is accidentally opened.

The following general procedure will serve as a guide when you install dishwashing machines. Set the dishwasher in position and level the machine. If the machine has adjustable legs, these should be used for leveling. Where adjustable legs are not provided, metal shims may be used to level the unit.

Connect the hot-water inlet to the hot waterline, using the proper fittings for the make and model of machine being installed. Water supplied must be at least 180 °F, or a booster-type heater must be installed. Connect the cold-water inlet to the machine; this is used to temper the water in the washing side of the machine. The pipe sizes vary according to the machine and fittings used. Follow the drawings and specifications for the hookup of the machine concerned, as only general information is covered here.

Install a steam supply line of proper size from the main steam line to the dishwasher. Then install a steam trap on the condensate return line. Be sure the steam trap is of the PROPER SIZE and designed for the steam pressure available. Pipes should be insulated (or lagged), as required; information on lagging is provided in chapter 3 of this training manual.

Tables on each end of the dishwasher are convenient for the operators. When installing these tables, fit the ends of the tabletops over the lip of the dishwasher to ensure a watertight connection and smooth operation.

The tables should be lined up carefully with the rack tracks and then bolted to the dishwasher. Be sure the tabletops are level with the rack tracks. Use gaskets or metal shims to compensate for variations in the thickness of the tabletops. Fit the soiled-dish end of each table with guide blocks or side flanges to guide racks onto rack tracks in the dishwasher.

Bolt the tables to the rim of the dishwasher, using countersunk screws or suitable bolts, or weld them to the rim of the dishwasher under the tabletop. If you have a choice, use bolts and soft washers to prevent leaking. Bolts and washers are better, of course, if you have to unfasten or remove the tables.

RANGES

Most ranges are composite pieces of equipment and may include any combination of units,

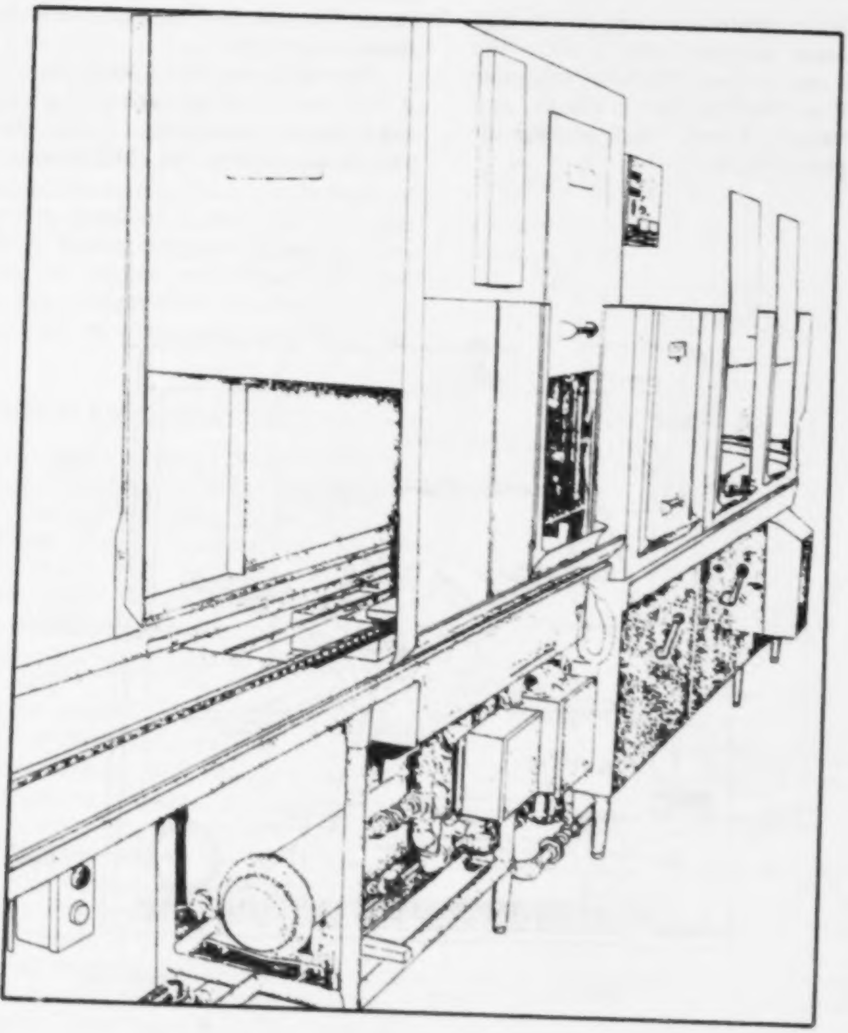

Figure 2-43.—Dishwashing machines, multiple-tank.

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such as a cooking top, oven, broiler, griddle, and deep-fat fryer. They may be heated by electrical heating elements, oil burners, or gas burners. Whatever the heating device, it must be maintained in a safe and economical operating condition. Utilitiesmen have various responsibilities in the installation of oil- and gas-fired equipment. Since these are the types generally used in Navy galleys, they are our primary concern.

When new equipment is received for installation, all the assemblies, subassemblies, and accessories must be inspected to see that they are all present, in good condition, and properly assembled. The equipment should be unpacked as near to the site of installation as possible.

To assemble, separate the components and accessories of one complete unit. Follow the manufacturer's instructions carefully; assemble one unit at a time. Seal all joints, cracks, and openings that might permit heat leakage or interfere with proper draft.

When ranges or ovens are installed along a combustible wall or partition, they must be at least 18 inches from the wall. As additional protection, erect a shield of fire-resistant material.

Good ventilation of ranges and ovens—including flue connections and room vents—is mainly attributable to selecting the correct site. Generally speaking, ovens and ranges should NOT be directly vent connected. The best way to vent three or more pieces of equipment is to use a hood, which extends 6 inches beyond all sides of the cooking surfaces. The hood should be connected to an adequate exhaust duct.

When a direct flue is installed, an approved draft diverter should be used under the manufacturer's instructions. Other than the draft diverter, install an adequately sized automatic draft check in the flue line as close as possible to the equipment connection.

For safety and best operation, never obstruct a flue. Assure that enough air is allowed to enter the room to compensate for air removed by the ventilating system and combustion.

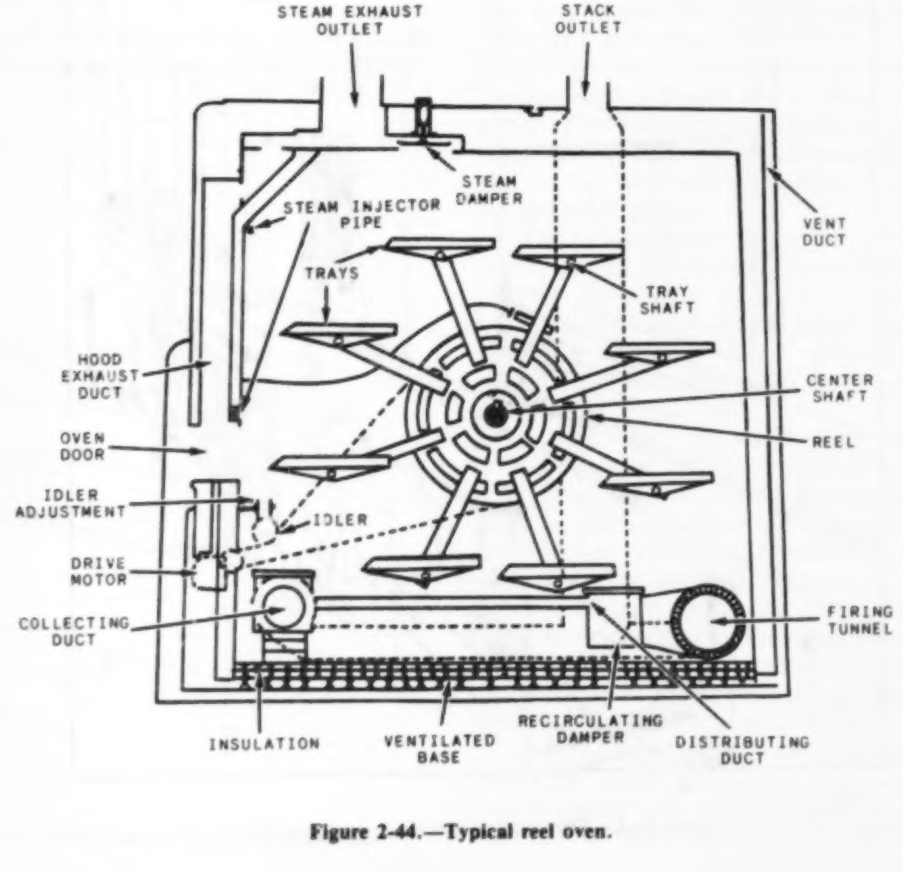

STEAM EXHAUST OUTLET
STACK OUTLET
STEAM DAMPER
STEAM INJECTOR PIPE
VENT DUCT
TRAYS
TRAY SHAFT
HOOD EXHAUST DUCT
CENTER SHAFT
OVEN DOOR
REEL
IDLER ADJUSTMENT
IDLER
DRIVE MOTOR
COLLECTING DUCT
FIRING TUNNEL
INSULATION
VENTILATED BASE
RECIRCULATING DAMPER
DISTRIBUTING DUCT

Figure 2-44.—Typical reel oven.

BAKERY OVENS

Most large naval galleys have a bakery department that is usually separated from the main galley. Various types of bakery equipment are available, but coverage on this equipment is not provided in this training manual. Brief coverage is given, however, to bakery ovens.

Both sectional and cabinet types of ovens are commonly used in bakeshops at Navy activities. Another type is the reel (or revolving-tray) oven; a diagram of a typical reel oven is shown in figure 2-44. The reel oven has a horizontal circular platform that revolves slowly; the loading and unloading are done at the same door. Bake ovens may be gas-fired, oil-fired, or electrically heated.

The installation of ovens may vary, depending upon the type of oven and the manufacturer. To ensure proper installation, follow carefully the drawings and specifications that accompany ovens. Only a few general details, which apply to most ovens, are provided here.

Most large model baking ovens are installed on a masonry hearth. Gas-fired equipment must be placed on masonry hearths if the bottom of the combustion chamber is less than 8 inches above the floor. Baking ovens are vented basically the same as the ranges and ovens discussed previously. The temperature is controlled by thermostats of the same type used on range ovens.

HOT-WATER HEATERS

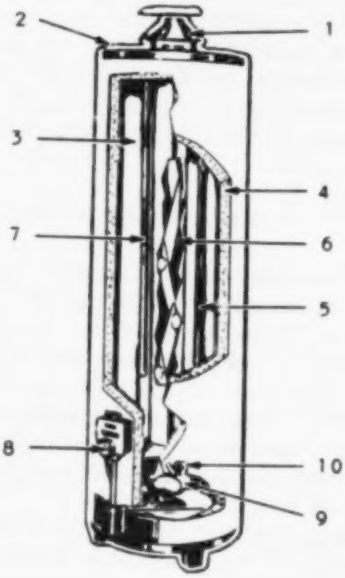
Clean, hot water is required in many installations for domestic and industrial use. Since boiler water cannot be used for this purpose, because of the chemicals added, it is necessary to heat other water. Water may be heated in tanks equipped with coiled piping through which the boiler water circulates; the water may be heated in independent units that are heated by electricity, gas, oil, or coal.

Domestic hot-water heaters are built in various sizes from 20- to 50-gallon capacities. Industrial type hot-water heaters are designed to heat thousands of gallons of water, depending upon the amount an installation uses.

Modern hot-water heaters are self-contained and require little attention, since they are fully automatic. The diagram of a gas-operated hot-water heater is shown in figure 2-45. These units are cylindrical in shape, and they have diameters ranging from about 12 to 30, 40, and 50 inches, depending upon their capacity. The tank is constructed of galvanized sheet metal, which may be lined with a composition of glass to resist corrosion of the tank lining and prevent contamination of the water. The combustion chamber is in the lower section. This chamber is vented by a baffled flue that extends through and ends at the top of the tank. The entire tank is insulated to prevent the escape of heat. It is also equipped with a thermostat that can be adjusted to maintain a certain water temperature. Safety features that make the hot-water heater automatic are also in the unit.

Both the cold-water inlet and the warm-water outlet are at the top of the tank. These tappings are usually marked INLET and OUTLET. However, if there is a question in your mind as to which is the inlet and which is the outlet, just remember that the cold-water inlet pipe extends over halfway into the tank, but the outlet pipe does not. There is usually a drain valve at the bottom of the tank.

You must ensure the dip tube is installed on the cold-water side or inlet to allow the cold water to go to the bottom of the heater and not cool the water at the top.



1. Draft diverter.
2. Relief valve opening.
3. Storage tank.
4. R-form insulation.
5. Dip tubes.
6. Flue baffle.
7. Anode rod.
8. Controls.
9. Burners.
10. Drain valves.

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Figure 2-45.—A gas-fired hot-water heater.

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Tools and Their Uses, NAVEDTRA 10085-A2, Naval Education and Training Program Management Support Activity, Pensacola, Fla., 1988.

CHAPTER 3

PLUMBING

Learning Objective: Identify installation methods and types of equipment used in laying sewer and water systems.

One of the principal duties of the Utilitiesman in the Navy is PLUMBING. Plumbing includes the installation, maintenance, and repair of piping, fixtures, and appliances used at shore activities for the collection of sanitary sewage, storm water, and other wastes and for the distribution of water, gas, compressed air, fuels, lubricants, and other fluids.

To become a good plumber, you need to learn information on pipe materials, fittings, tools, and methods and procedures used in plumbing work. You will train and learn a lot about plumbing under a good supervisor or instructor. In time, you will develop the skills of an experienced plumber.

This chapter deals primarily with pipe materials, fittings, fixtures, and the various skills needed for installation of a plumbing system. Instruction is provided on two major phases of plumbing: sewer systems and water service. The next chapter concerns repairs and adjustments that you may be called upon to make in existing plumbing systems.

You will not find everything you need to know to become a master plumber in this training manual. However, by studying the material in this chapter and the one following, and then putting into practice what you learn, you will be on your way toward developing the basic skills of this trade.

SEWER SYSTEMS

The main purpose of a sanitary sewage collection system is to transfer sewage from a source to a sewage treatment plant. Raw sewage that is not transferred safely to a sewage treatment plant can harm human beings because it contains many harmful bacteria.

The sanitary sewage collection system includes all house sewers, laterals, branches, interceptors, force mains, and so on. These and other related terms are explained in chapter 7 of this manual. In this discussion, you will be primarily concerned with materials and operations required in the installation of sewer systems.

The installation of an underground sewer system for transferring domestic sewage from the source to the sewage treatment plant includes (1) trenching and grading, (2) measuring and cutting pipe, (3) laying pipe, (4) joining pipe, (5) testing, and (6) backfilling and tamping. Trenching and grading are discussed in the first section of this section of this chapter. Information on the other phases of sewer installation is discussed in other sections of the chapter.

TRENCHING AND GRADING

A trench may be excavated either manually or with heavy equipment, depending primarily on the size of the job and the type of soil to be removed. On a large job where the soil is suitable for machine work, your project supervisor arranges to have Equipment Operators operate those pieces of equipment necessary to excavate, or dig the trench. When it is impractical to use machines, you have to do the job with a pick and shovel. Whichever method is used, the trench must be dug wide enough (2 feet minimum) to allow ample working room to join pipe sections. The bottom of the trench must also be sloped in the direction of flow so that sewage traveling through the pipeline laid in the trench is not restricted. On most jobs, an Engineering Aid is on hand to check elevations to ensure that the slope of the trench is close to the slope where the pipe is to be laid. On most jobs, Engineering Aids establish a system of batter boards and grade bars (explained later) for you to accurately check the slope of the pipeline as it is being laid in the trench. Check the job specifications for the proper grade of the sewer line being installed. If specifications are not available, a rule of thumb is to slope the trench one-fourth inch per foot. This is the grade at which sewage flows freely through a pipe.

When a pipeline is to be laid in stable soil, such as hard clay or shale, the trench should be excavated below the pipe grade. If bell-and-spigot pipe is to be used, excavation must be made for the bells. See that enough undisturbed earth remains at the bottom of the trench so the pipe, both joints and barrel, rests on and is fully supported by undisturbed earth. In areas where the temperature drops below freezing, the trench must be excavated deep enough for the pipeline to be below the frost line. Pipes that cross under roads or areas of vehicle travel must be buried in trenches at least 4 feet deep.

The sides of excavations, 4 feet or more in depth, or in which the soil is so unstable that it is not considered safe at greater depths, should be supported by substantial and adequate sheeting, sheetpiling, bracing, shoring, and so forth, or the sides should be sloped to the angle of repose. Surface areas adjacent to the sides should be well drained. Trenches in partly saturated, filled, or unstable soils must be suitably braced.

UNDERGROUND SEWAGE PIPING

Among the pipe materials installed underground by Utilitiesmen are cast-iron soil pipe, vitrified clay pipe, concrete pipe, and plastic pipe.

Cast-Iron Soil Pipe (CISP)

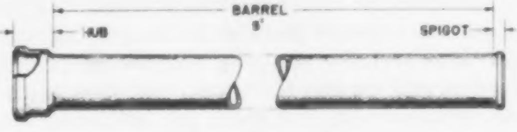
Cast-iron soil pipe and fittings are composed of gray, cast iron which is made of compact, close-grained pig iron, scrap iron and steel, metallurgical coke, and limestone. Cast-iron soil pipe is normally used in and under buildings, protruding from 2 to 10 feet from the building. (The *National Standard Plumbing Code-Illustrated* recommends at least 3 feet.) Here it connects into a concrete, plastic, or clay house sewer line. Cast-iron soil pipe is also used under roads or other places of heavy traffic.

If the soil is unstable, it is better to use cast-iron soil pipe. However, cast-iron soil pipe should not be used in soil containing cinders or ashes; the reason is that the soil may contain sulfuric acids, which cause the pipe to corrode and to deteriorate rapidly.

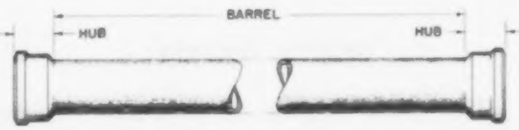
NOTE: If the soil contains cinders and ashes, instead of using cast-iron soil pipe, use vitrified clay or plastic pipe.

The cast-iron soil pipe used in plumbing installations comes in 5-foot and 10-foot lengths. Sizes of cast-iron soil pipe are 2, 3, 4, 6, 8, 10, 12, and 15 inches nominal inside diameter. It is available as single hub or double hub in design, as indicated in figure 3-1. Note that single-hub pipe has a hub at one end and a spigot at the other. The double-hub pipe has a hub at both ends. Hubs, or bells, of cast-iron soil pipe are enlarged sleevelike fittings. They are cast as a part of the pipe and are used to make a water- and pressure-tight joint with oakum and lead. Cast-iron soil pipe is generally available in two weights: standard or service (SV) and extra heavy (XH). The extra heavy pipe is used where superior strength is required; for example, under roadways, where the pipe may vibrate or settle slightly, and tall stacks. Standard or service weight pipe is adequate for most Navy base construction.

MEASUREMENTS.—Cast-iron soil pipe sections are generally 5 and 10 feet in length, but strictly speaking, this is not true. The reference to a 5-foot length of pipe applies to the laying length, not the overall dimensions. For clarity, first note that cast-iron soil pipe in 2-, 3-, 4-, and 6-inch-(inside) diameter sizes are in common use. The length of the bell for the 3-inch-diameter pipe



SINGLE-HUB PIPE



DOUBLE-HUB PIPE

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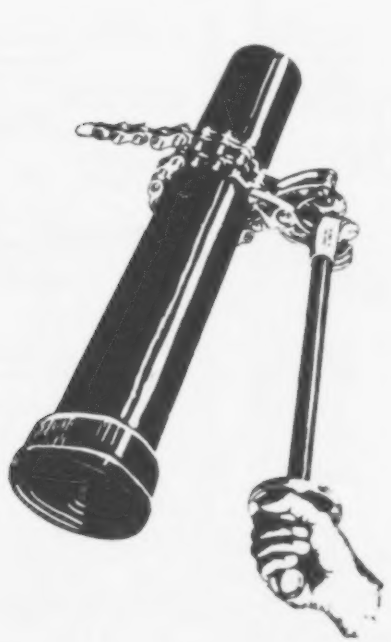
Figure 3-1.—Single-hub and double-hub cast-iron soil pipe.

is 2 3/4 inches; and for the 4- and 6-inch-diameter sizes, the length is 3 inches. Now note that while the laying length of a 4-inch-diameter cast-iron soil pipe is 5 feet, the overall length is 5 feet and 3 inches.

The most common measurement of cast-iron soil pipe, for a shorter length than 5 feet, is the overall measurement. When making this measurement for 4-inch pipe, you should take the desired length of pipe for the installation and add 3 inches to it for the bell.

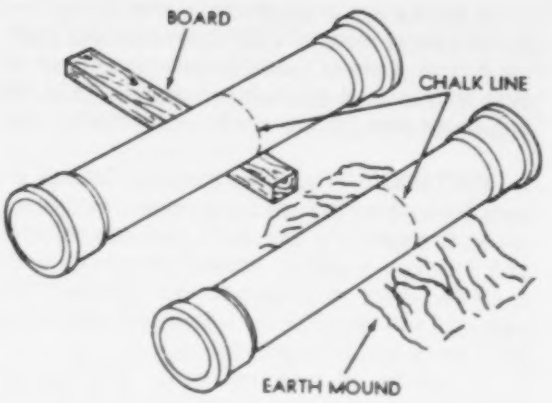
CUTTING.—Before joining cast-iron pipe, you often have to cut the pipe to provide the desired length. Cast-iron soil pipe can be cut with an abrasive cutter, a band saw, an hydraulic or manual snap cutter (fig. 3-2), or a hammer and chisel. The hammer and chisel method is slow and used only if other tools are not available. Here is a step-by-step procedure for cutting with a hammer and chisel.

- Mark or score the pipe with a triangular file entirely around the pipe where it is to be cut.
- Lay the pipe over a board or mound of earth at the point to be cut to support the pipe (fig. 3-3) and allow it to turn easily.



54.24.1

Figure 3-2.—Manual snap cutter.

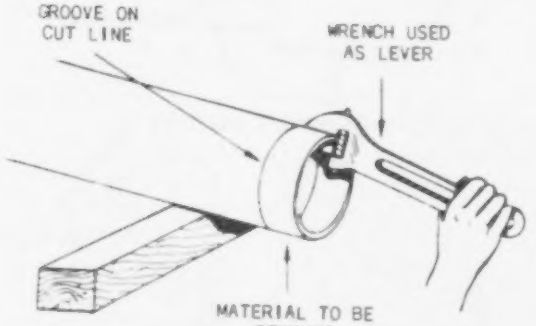


54.31.1

Figure 3-3.—Supporting soil pipe for cutting.

- Score the pipe with a cold chisel (not too sharp). Move the chisel a little at a time along the mark, tapping lightly with a hammer until the pipe is evenly scored all around.
- Continue to turn the pipe and strike the chisel with increasingly heavier blows until the pipe breaks evenly at this line.

Another means of cutting a short piece, 1 or 2 inches, is with a hacksaw and an adjustable wrench. Cut a groove with the hacksaw around the pipe to a depth equal to one-half the wall thickness of the pipe. Break away the section of pipe with an adjustable wrench, used as a lever, as shown in figure 3-4.



54.31.2

Figure 3-4.—Cutting cast-iron pipe with hacksaw and adjustable wrench.

A good point to remember is that if you have to cut a short piece of CISP (cast-iron soil pipe), cut it from a piece of double-hub pipe (a hub on both ends instead of a hub and spigot). Thus, the remaining pipe still has a hub, and it can be used.

FITTINGS.—Cast-iron soil pipe fittings are used for making branch connections, or changes in the direction of a line. Both cast-iron soil pipe and fittings are brittle, so exercise care to avoid dropping them on a hard surface. Some of the cast-iron soil pipe fittings which you may use in your work are described below.

A number of different types of bends are generally used on jobs involving cast-iron soil pipe. Some of the common types are the 1/16, 1/8, short sweep 1/4, long sweep 1/4, and reducing 1/4 bend. By observing figure 3-5, you can get an idea of the shape and appearance of each of these types of bends.

The 1/16 bend is used to change the direction of a cast-iron soil pipeline 22 1/2 degrees. A 1/8 bend is used to change the direction of a cast-iron soil pipeline 45 degrees. The SHORT SWEEP 1/4 bend is a fitting used to change the direction of a cast-iron soil pipeline 90 degrees in a closed space. The LONG SWEEP 1/4 bend is used to change the direction of a cast-iron soil pipeline 90 degrees, but more gradually than the short sweep 1/4 bend. The REDUCING 1/4 bend gradually changes the direction of the pipe 90 degrees, and in the sweep portion, it reduces nearly one size. A 4 by 3 reducing long sweep 1/4 bend has a 4-inch SPIGOT on one end, reducing 90 degrees to a 3 1/4-inch HUB on the other end. Note that for all CISP fittings, the spigot end is always listed first.

Tees connect branches to continuous lines. Learn to recognize the four designs of tees shown in figure 3-6. For connecting lines of different sizes, REDUCING tees are often suitable.

The TEST tee is used in stack and waste installations where the vertical stack joins the horizontal sanitary sewer (fig. 3-7). It is installed at this point to allow the plumber to insert a test plug and fill the system with water in testing for leakage. The test tee is also used in multistory construction.

The TAPPED tee is frequently used in the venting system; it is called the "main vent tee." The SANITARY tee is commonly used in a main stack to allow the takeoff of a cast-iron soil pipe branch.

There are four types of cast-iron soil pipe 90-degree Y-branches in general use, as shown in

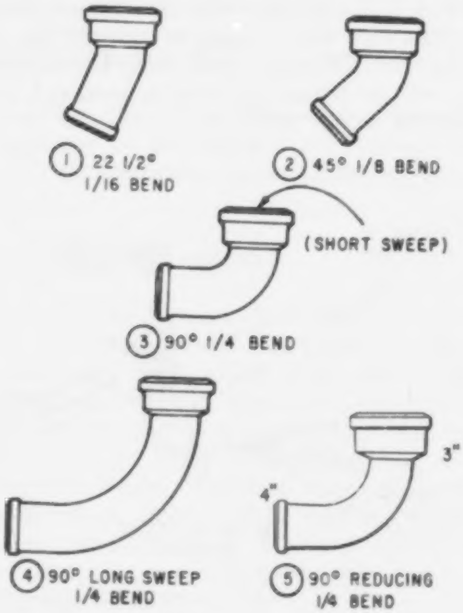


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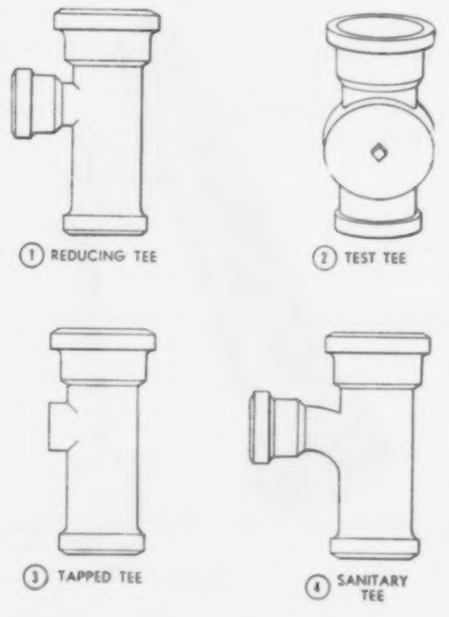
Figure 3-5.—Types of cast-iron soil pipe bends.



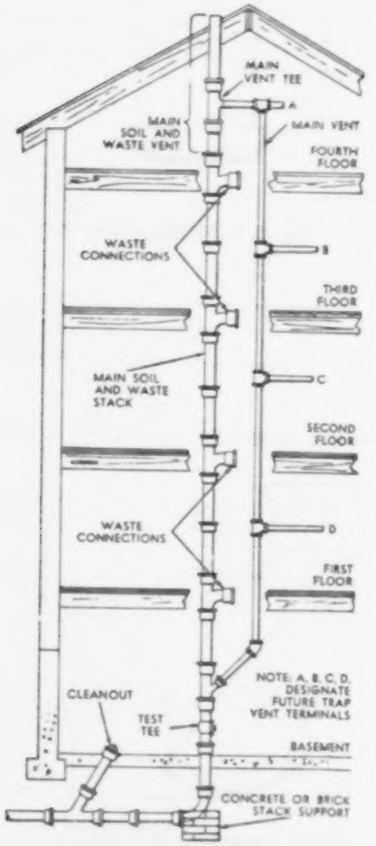
54.26

Figure 3-6.—Cast-iron soil pipe tees.

view (A), figure 3-8. These are normally referred to as combination Y and 1/8 bends.

The STRAIGHT type of 90-degree Y-branch has one section that is straight through and a takeoff on one side. The side takeoff starts out as a 45-degree takeoff and bends into a 90-degree takeoff. This type of branch is used in sanitary sewer systems where a branch feeds into the main, and it is desirable for the incoming branch to feed into the main as nearly as possible in a line parallel to the main flow.

The REDUCING 90-degree Y-branch is similar to the straight type. However, as indicated in view (A), figure 3-8, the branch takeoff of the 90-degree Y-branch is smaller than the main straight-through portion. It is generally used the same as the straight type, except the branch coming into the main has a smaller sized pipe than the main.


MAIN
VENT TEE
A
MAIN
SOIL AND
WASTE VENT
MAIN VENT
FOURTH
FLOOR
WASTE
CONNECTIONS
B
THIRD
FLOOR
MAIN SOIL
AND WASTE
STACK
C
SECOND
FLOOR
WASTE
CONNECTIONS
D
FIRST
FLOOR
NOTE: A, B, C, D,
DESIGNATE
FUTURE TRAP
VENT TERMINALS
CLEANOUT
TEST
TEE
BASEMENT
CONCRETE OR BRICK
STACK SUPPORT

54.38

Figure 3-7.—Typical stack and vent installation.

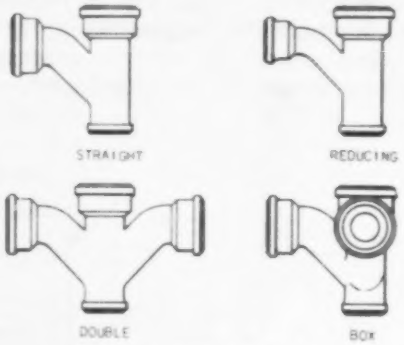
The DOUBLE 90-degree Y-branch (or DOUBLE COMBINATION Y and 1/8 BEND) is easy to recognize since there is a 45-degree takeoff bending into a 90-degree takeoff on both sides of the fitting, as shown in view (A). It is very useful as an individual vent.

The BOX type of 90-degree Y-branch has two takeoffs. It is designed for each takeoff to form a 90-degree angle with the main pipe. The two takeoffs are spaced 90 degrees apart.

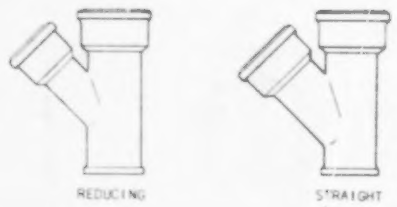
There are two types of cast-iron soil pipe 45-degree Y-branches. These are the reducing and the straight types; both are shown in view (B), figure 3-8.

The REDUCING type is a straight section of pipe with a smaller sized 45-degree takeoff branching to one side. There are different sizes of this fitting. As an example, a 4 by 4 by 3 reducing 45-degree Y-branch has a 4-inch-straight portion with a 3-inch 45-degree takeoff on one side.

The STRAIGHT type of 45-degree Y-branch, or true Y, is the same as the reducing type, except that both bells are the same size. It is used


STRAIGHT
REDUCING
DOUBLE
BOX

A. TYPES OF CAST-IRON SOIL PIPE, 90° Y-BRANCH


REDUCING
STRAIGHT

B. TYPES OF CAST-IRON SOIL PIPE, 45° Y-BRANCH.

43.28

Figure 3-8.—Types of cast-iron soil pipe, 90- and 45-degree Y-branches.

to join two sanitary sewer branches at a 45-degree angle.

Cleanout plugs are installed to allow the removal of stoppages from waste lines. View A, figure 3-9, shows one type of cleanout plug. It consists of an iron ferrule caulked with the hub of a pipe or fitting. The top opening is taped and threaded to allow a pipe plug to be screwed into it. Cleanouts should not be more than 50 feet apart in horizontal 4-inch building drain lines in a straight run. When the change of direction is greater than 45 degrees (or a 1/8 bend), you must install a cleanout plug.

The long hub, or Sisson, type of cleanout (view B, fig. 3-9) is used as an insert to an existing line. The long hub allows you to push it up far enough to clear the other bell of the bottom pipe, and then to drop the fitting in place.

Another type of adapter is a sewer thimble (or saddle). This is a special fitting that is used to tie into an existing sewer line. (See view C, fig. 3-9.) It has a hub on one end, bending around to almost 45 degrees, with a flange near the opposite end. To install, cut a hole halfway between the top and the center line in the sewer line. The hole should be the same size as the outlet portion of the thimble beyond the flange. Slip the thimble into the opening until the flange seats on the sewer pipe. Using oakum and concrete, grout around the thimble to make a watertight joint.

The increaser (fig. 3-10) is used to increase the size (diameter) of a straight-through line. It is often used at the top of a main stack and vent.

A closet bend (fig. 3-11) is a special fitting inserted into a soil branch. This enables the soil

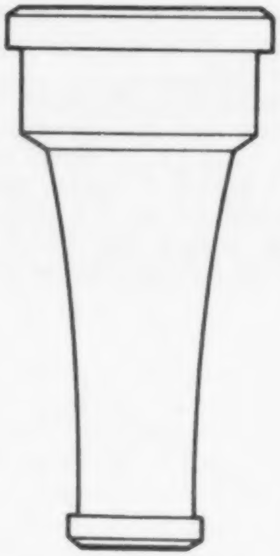
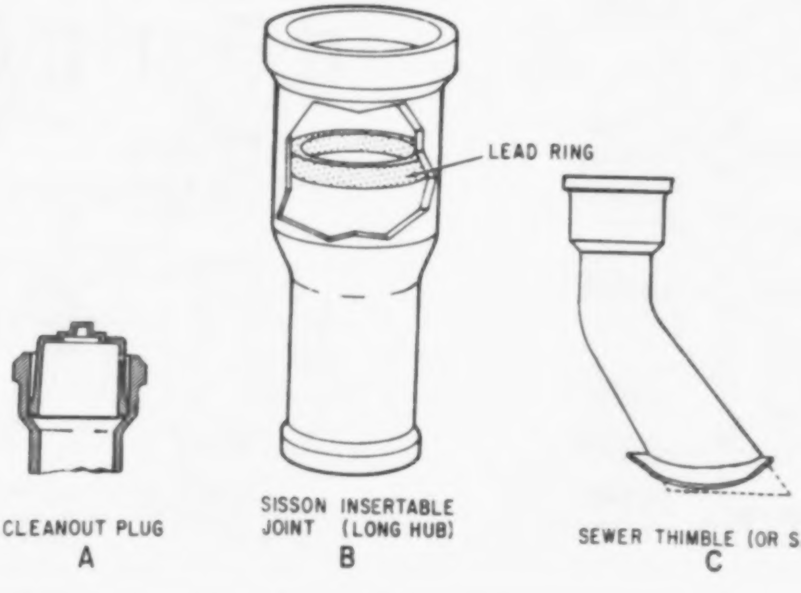


Figure 3-10.—Increaser.



54.29

Figure 3-9.—Adapter-type cast-iron soil pipe fittings.

branch to be fitted to the water closet. It may be untapped or have either one or two side taps for waste or vent use. Closet bends are made in different styles to fit different types of floor flanges (rims for attachment). One type (view A, fig. 3-11) has a spigot end for caulking into the soil line and a scored (marked with lines) end to fit into the floor flange. The scoring makes it easier to cut the bend to the desired length for a given connection. Another type, shown in view B, figure 3-11, has a hub connected to the floor flange with a sleeve or short length of pipe. The end caulked into the soil line is scored for cutting to size. Still other types may be scored for cutting at both ends or may be of the regular hub-and-spigot pattern.

Regular offsets, view A, and 1/8 bend offset, view B, figure 3-12, are used to carry the soil or waste lines past an obstruction such as a part of the building. The 1/8 bend offset gives a smoother transition than the regular one. Fittings for no-hub cast-iron pipe are identical to the others, except there are no hubs.

JOINING.—Various methods are used in joining pipe. This means that you must know the procedure to follow in making various types of joints required for the kind of pipe to be joined. Lead and oakum joints, oakum and lead-wool joints, compression joints, and no-hub joints are means for connecting pipes. Figure 3-13 shows these types of joints. However, if oakum is not

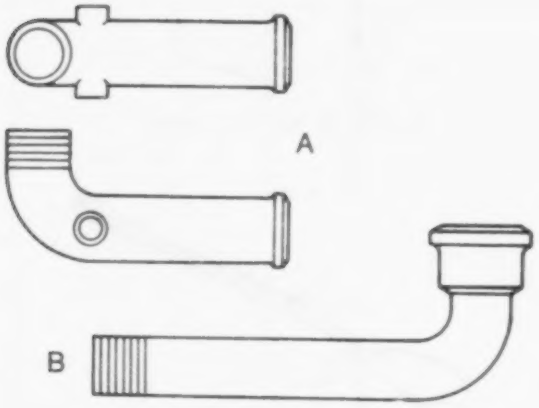


Figure 3-11.—Cast-iron soil pipe closet bends.

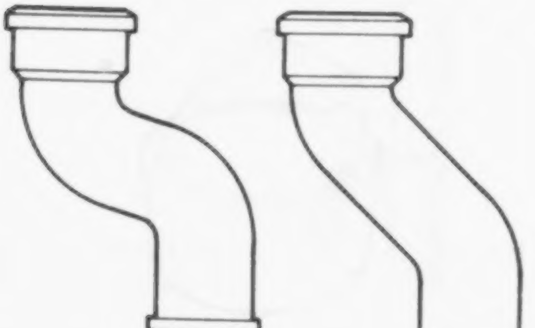
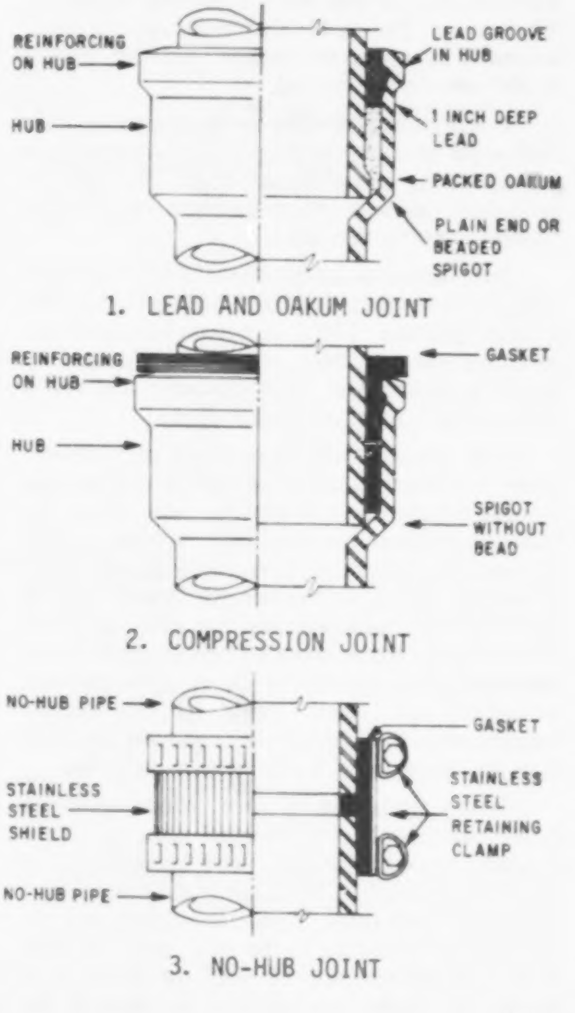

A. OFFSET
B. 1/8 BEND OFFSET

Figure 3-12.—Offsets.


REINFORCING ON HUB
HUB
LEAD GROOVE IN HUB
1 INCH DEEP LEAD
PACKED OAKUM
PLAIN END OR BEADED SPIGOT
1. LEAD AND OAKUM JOINT
REINFORCING ON HUB
HUB
GASKET
SPIGOT WITHOUT BEAD
2. COMPRESSION JOINT
NO-HUB PIPE
STAINLESS STEEL SHIELD
NO-HUB PIPE
GASKET
STAINLESS STEEL RETAINING CLAMP
3. NO-HUB JOINT

54.450

Figure 3-13.—The various joints presently being used to connect CISP and fittings.

available, cotton braid or jute can be used as a substitute. Oakum is made of hemp or jute fibers, impregnated with a bituminous compound and loosely twisted or spun into rope or yarn.

In making caulked joints, you need various types of equipment. Because of the importance of this equipment, the common types of caulking equipment and safety procedures to be observed when making caulked joints are discussed.

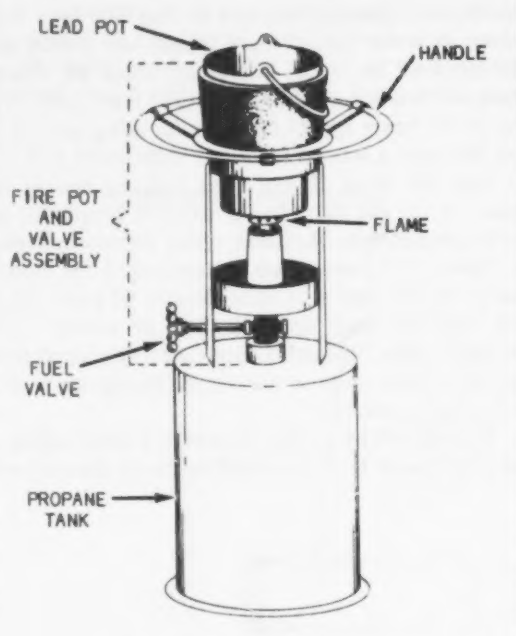
Equipment frequently used in making caulked joints in cast-iron soil pipe includes the melting furnace, melting pot, and plumber's ladle. These components are shown in figure 3-14. The melting furnace is a portable gas-burning furnace used to melt lead. The melting pot is made of cast iron and contains the lead while it is being melted on the furnace. The ladle, also made of cast iron, is used to spoon up the molten lead and carry it to the joint to be poured.

Several types of melting furnaces are available. Follow the manufacturer's instructions when you are operating a particular type. The general procedure below is for operating a MAPP-gas-burning melting furnace.

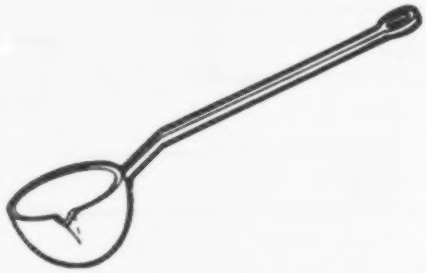
This type of furnace consists of a fire pot and valve assembly that mounts directly on a portable propane gas tank. The tank is detachable and can be recharged with fuel. A propane furnace, as shown in figure 3-14, lights instantly and burns with a high-temperature blue flame.

Look for leaks before you light the furnace. There is always a danger of explosion from gas leakage around the connections and valves. To light the propane furnace, fold or twist a piece of paper and light it. Hold the flame up and under the burner orifice of the fire pot. Stand back as far as possible and open the fuel valve until the burner lights. If the valve is opened too much or too rapidly, the pressure of the escaping gas may extinguish the lighter flame. If this should happen, close the fuel valve immediately and then light the paper before you reopen the valve.

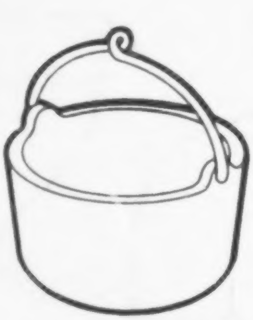
Molten lead is dangerous. Most accidents occur because the Utilitiesman ignored safety procedures. When molten lead is handled, be SAFETY MINDED. Moisture in the molten lead makes the lead splash from the melting pot. If you suspect moisture in the lead, heat the lead with a gasoline blowtorch until the moisture is driven off. Now, you can add the lead to the melting pot. If the lead is not dry, the moisture turns into steam when it strikes the molten lead. This molten lead may spatter high enough to reach



1. PROPANE MELTING FURNACE



2. PLUMBER'S LADLE



3. MELTING POT

54.451

Figure 3-14.—Melting furnace, plumber's ladle, and melting pot.

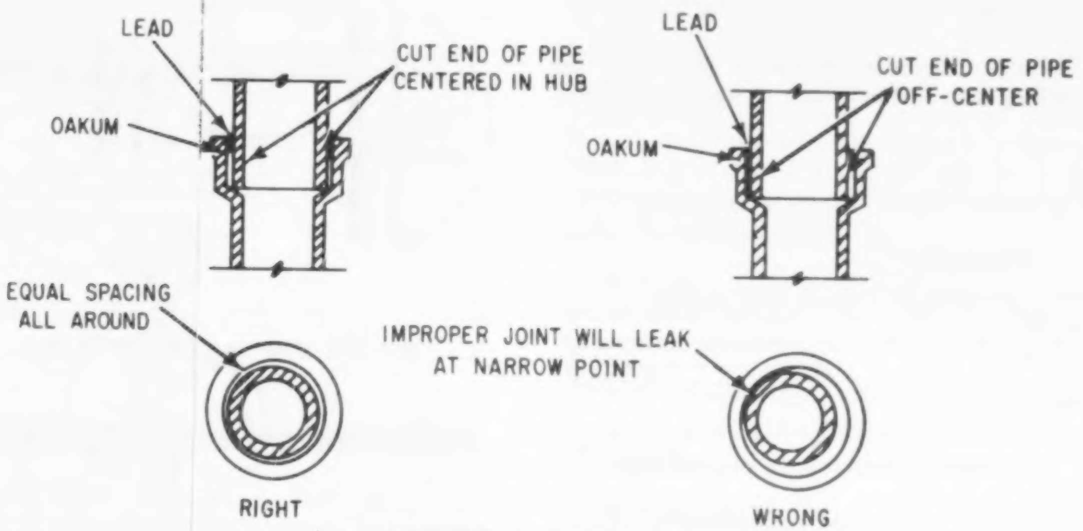
your face or eyes. Make sure the plumber's ladle is free of moisture too.

When lead is melted, certain products of oxidation, known as slag, form on top of the molten metal. The slag must be removed from the lead before it can be used for pouring a joint. Scoop it up in the plumber's ladle. Use care in disposing of the slag.

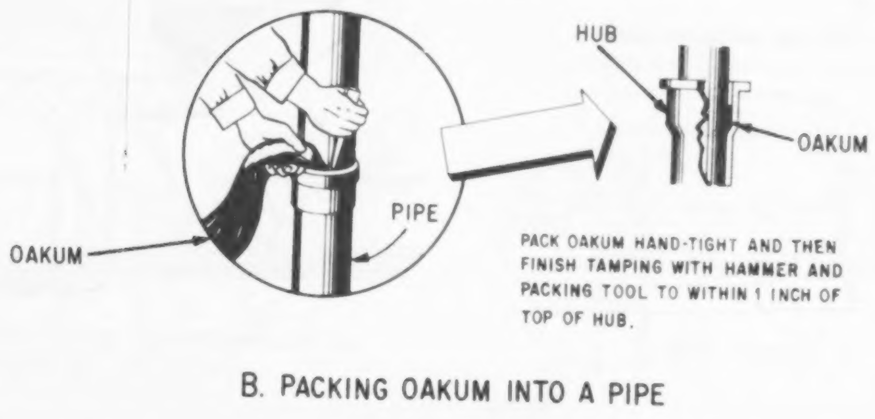
Always preheat the ladle before you dip it into the lead because a cold ladle chills and solidifies some metals. When the ladle is in steady use, keep it hot by hanging it over the edge of the pot. In loading the ladle, use the bottom of it to push back the dross (or scum) on top of the lead, exposing enough clean lead so that the ladle can be filled and withdrawn without dross. Do not disturb the molten lead more than is necessary.

Wear goggles, gloves, and protective clothing when melting and pouring the lead. Keep out of range of flying lead even though the joint appears dry. Also, see that drops of perspiration do not drop into the pot of hot lead.

When making vertical caulked joints, you should wipe the hub-and-spigot ends of the pipes to remove moisture and foreign matter. **WATER CAUSES MELTED LEAD TO SPATTER AND SERIOUS BURNS MAY RESULT.** If the ends are wet, dry them with a blowtorch. Slide the spigot end of one pipe into the hub of the other and align the joint so the cut end is in the center of the hub, as shown in view A, figure 3-15. As


LEAD
CUT END OF PIPE CENTERED IN HUB
OAKUM
EQUAL SPACING ALL AROUND
RIGHT
LEAD
CUT END OF PIPE OFF-CENTER
OAKUM
IMPROPER JOINT WILL LEAK AT NARROW POINT
WRONG

A. CENTERING BEFORE CAULKING


HUB
OAKUM
PIPE
OAKUM

PACK OAKUM HAND-TIGHT AND THEN FINISH TAMPING WITH HAMMER AND PACKING TOOL TO WITHIN 1 INCH OF TOP OF HUB.

B. PACKING OAKUM INTO A PIPE

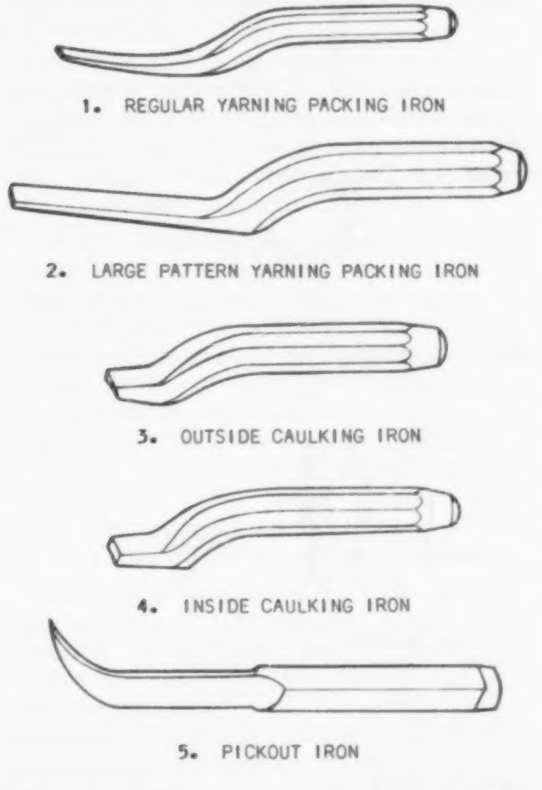
54.452

Figure 3-15.—Caulking cast-iron joints.

shown in view B, figure 3-15, use packing (yarning) irons (1 and 2, fig. 3-16), and pack a layer of spun or twisted oakum into the hub completely around the joint. Repeat with more layers until the hub is packed to about 1 inch from the top. Compress the oakum thoroughly to make a solid bed for the lead and to prevent leakage of the joint. With a plumber's ladle (2, fig. 3-14), pour melted lead carefully into the joint until it rises slightly above the top rim of the hub (fig. 3-17). Dip up enough lead with the ladle to make the joint in one pouring. Allow a minute or two for the lead to harden.

CAUTION: To avoid using a wet ladle to dip hot lead, you must heat the ladle. Remember, moisture causes hot lead to spatter out of the melting pot. Always wear a protective face shield and gloves when working with hot lead.

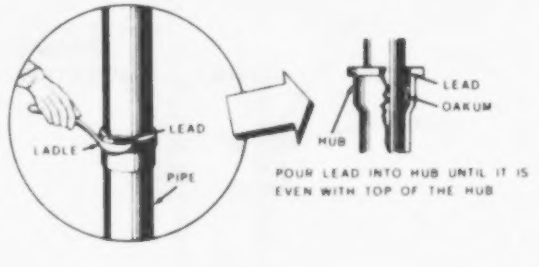
Perform caulking operations using an inside caulking iron first and then an outside caulking iron (4 and 3, fig. 3-16). Drive the lead down upon the oakum and into contact with the spigot surface on one edge and against the inner surface of the hub on the other. Strike the caulking iron gently but firmly with a hammer. Caulking the lead too tightly can crack the pipe. A cracked pipe or fitting must be replaced. A pickout iron (5, fig. 3-16) should be used when oakum and lead must be removed from a joint.


1. REGULAR YARNING PACKING IRON
2. LARGE PATTERN YARNING PACKING IRON
3. OUTSIDE CAULKING IRON
4. INSIDE CAULKING IRON
5. PICKOUT IRON

54.453

Figure 3-16.—Packing and caulking irons.

Sometimes a joint must be made in a vertical line with the hub upside down, as in a vent stack. Prepare ends of pipes and pack the joint with oakum, as shown in view B, figure 3-15. Clamp a joint runner around the pipe. Raise the end of the joint runner, as shown in figure 3-18, and make a funnel in the raised end, using fine clay,


LEAD
OAKUM
LADLE
LEAD
PIPE
HUB
POUR LEAD INTO HUB UNTIL IT IS EVEN WITH TOP OF THE HUB

54.454

Figure 3-17.—Pouring hot lead into a joint.

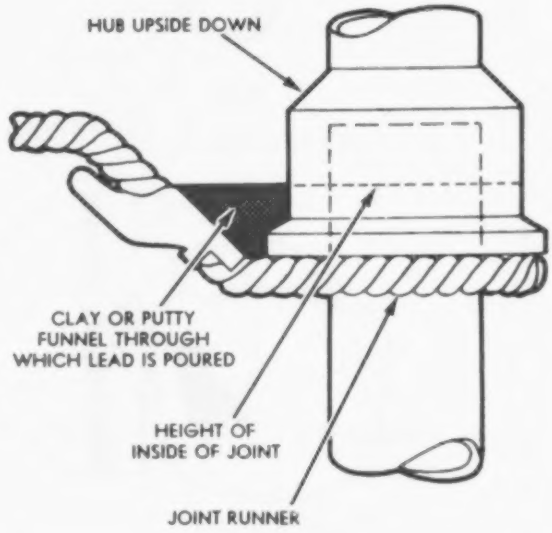
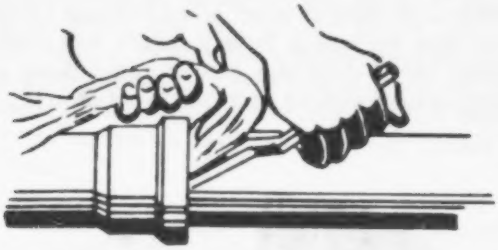

HUB UPSIDE DOWN
CLAY OR PUTTY FUNNEL THROUGH WHICH LEAD IS POURED
HEIGHT OF INSIDE OF JOINT
JOINT RUNNER

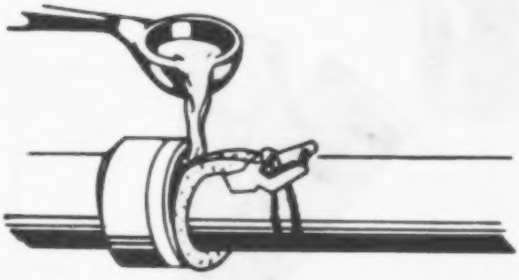
Figure 3-18.—Making an upside-down joint.

putty, or plaster. The funnel must be at least as high as the inside height of the lead portion of the joint.

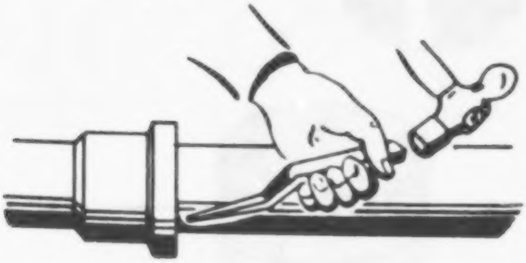
CAUTION: Be sure the funnel is dry before the lead is poured to prevent blowout of the hot lead from steam. Pour the lead and allow it to cool before removing the joint runner. Caulk the lead with a caulking iron to adjust it to the inside walls of the hub.



A. PACK JOINT HALF FULL OF OAKUM



B. CLAMP JOINT RUNNER AROUND PIPE AND POUR LEAD INTO JOINT. PLACE PUTTY OR CLAY ON BACKSIDE OF RUNNER TO PREVENT LEAD FROM RUNNING UNDER RUNNER CLAMP.



C. REMOVE JOINT RUNNER WHEN LEAD HAS COOLED AND CAULK JOINT.

54.455

Figure 3-19.—Making a joint on horizontal piping.

When making a horizontal caulked joint, you must prepare the ends of the pipes by packing the joint with oakum, as shown in view A, figure 3-19. Clamp a joint runner around the pipe; place a small piece of oakum between the clamp and pipe to seal the gap and prevent hot lead from running out the joint; and then, fill the joint with melted lead, as shown in view B, figure 3-19. After the lead hardens, remove the runner and trim off the surplus lead with a chisel. Caulk the lead in the same way as a vertical joint, as shown in view C, figure 3-19.

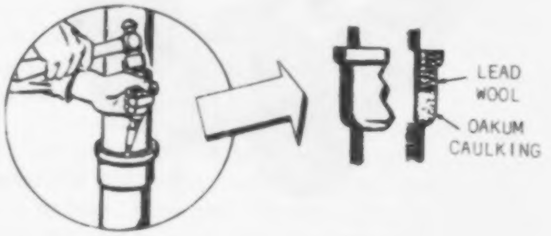
When making a lead-wool joint in cast-iron soil pipe, you need a yarning iron and caulking irons. This is a cold-caulked joint and should be used where a line is underwater or in a wet place where molten lead cannot be used. Before starting the joint, place the spigot end of the pipe to be installed in the hub of the soil pipe. Make sure the pipe is securely blocked with braces to prevent shifting. The pipe must also be centered in the hub so the thickness of the joint is uniform. With the pipe braced firmly and in proper position for joining, make the joint following the procedure given below:

- Pack oakum in the joint to within 1 inch of the top of the hub. Use a ball peen hammer and a packing iron to tamp the oakum tightly in the joint.

- Pack two 1/2-inch layers of lead wool over the oakum.

- Tamp the lead wool tightly into the joint, using the caulking irons and the ball peen hammer. (See fig. 3-20.)

In making a compression joint, you should be sure to clean the internal surface of the hub and



54.34

Figure 3-20.—Tamping lead wool.

the external surface of the pipe and/or fitting to be joined. When using a cut pipe, you can remove the sharp edge by peening or by lightly filing the rough edge to permit the pipe to slide and NOT dig into the gasket. Insert the gasket into the hub, and make sure the retaining flange or collar of the gasket is next to the face of the hub. Be sure to use the recommended lubricants available (normally a soap or an adhesive type). They are applied to the inside of the gasket. Align the spigot and hub to be joined, keeping the spigot and hub in a straight line. The spigot end of the pipe or fitting can be forced into the gasket by using an assembly tool such as that shown in figure 3-21.

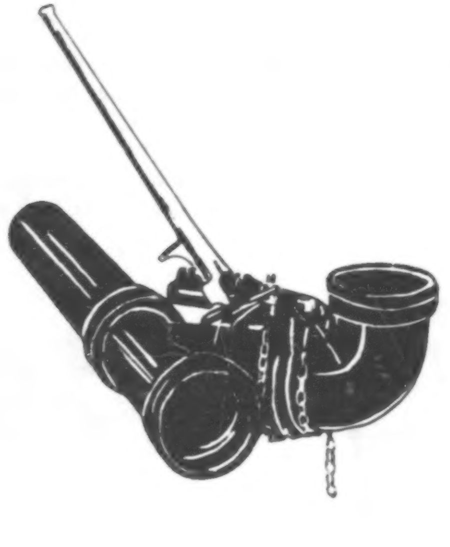
In making a no-hub joint, place a neoprene or an elastomeric gasket on the end of one pipe and the stainless steel shield and clamp assembly, as shown in figure 3-22, on the end of the other pipe. Firmly seat the pipe ends against the integrally molded shoulder inside the gasket. Slide the shield and clamps into position over the gasket and tighten the stainless steel clamps alternately and firmly to about 60 inch-pounds of torque.

Vitrified Clay and Concrete Pipe

Vitrified clay pipe is made of moistened powdered clay. It is available in laying lengths of 2, 2 1/2, and 3 feet and in diameters ranging from 4 to 42 inches. Like cast-iron soil pipe, it has a bell end and a spigot end to make joining easy. After the pipe is taken from the casting, it is glazed and fired in large kilns to create a moistureproof baked finish. It is used for house sewer lines, sanitary sewer mains, and storm drains. The types of fittings for clay pipe are bends, tees, and Y-branches primarily.

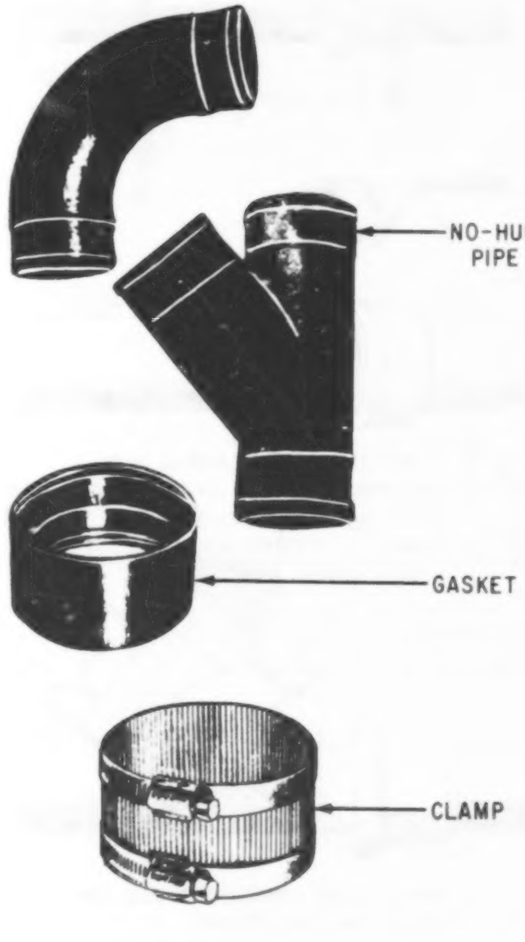
You may have to use plain precast concrete pipe for sewers in the smaller sizes—less than 24 inches. This pipe is not reinforced with steel. This concrete pipe is similar to vitrified clay pipe in measuring, cutting, joining, and handling.

HANDLING AND STORING CLAY PIPE.—Be careful when you store and handle clay pipe because it is very fragile and cracks easily. Never drop clay pipe or roll it down an embankment without control. Do not drop heavy



54.456

Figure 3-21.—Compression joint assembly tool.



54.457

Figure 3-22.—No-hub pipe and fittings.

objects on clay pipe. When backfilling a trench, do not use fill with rocks or other heavy debris in it. Tamp by hand or by pneumatic tampers, bearing in mind the density of the backfill. Clay pipe should be laid in a trench and bedded evenly and firmly, the more perfect the bedding, the greater the load the pipe can sustain. Common sense can save a lot of time by eliminating rework.

CUTTING.—Vitrified clay and concrete pipe, both available in such short lengths, seldom need cutting except for manholes and inlets. If, after measurement, you have to cut vitrified clay or concrete pipe, score it with a chisel, deepening the cut gradually until the pipe breaks cleanly at the desired point. Vitrified clay and concrete pipes may be cut with CISP "snap-off" or "chain" cutters.

FITTINGS.—Figure 3-23 shows some common fittings used with vitrified clay and concrete pipes. Note that these types of pipes are used outside the building. This greatly reduces the number of different types of fittings required.

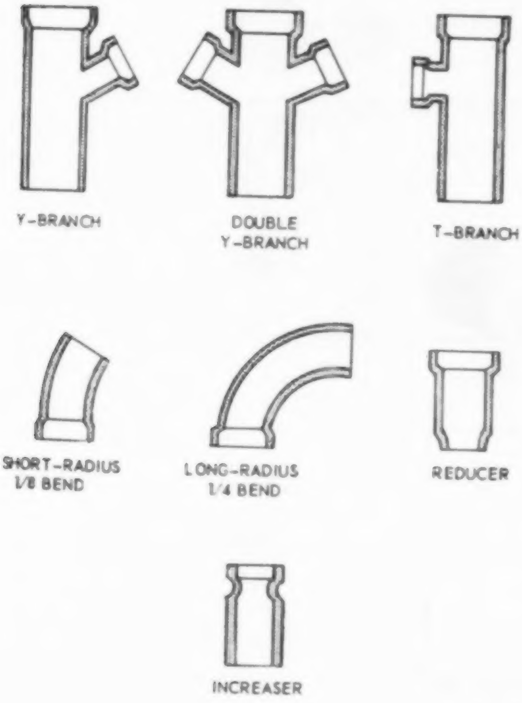


Figure 3-23.—Cross section of clay or concrete fittings.

JOINING.—Joints on vitrified clay and concrete pipe may be made of cement or bituminous compounds. Cement joints may be made of grout, which is a mixture of cement, sand, and water. The following procedure may be used as a guide in joining pipe with grout. This procedure is very similar for joining pipe with bituminous compounds.

- Insert the spigot of one length of pipe into the bell of another and align the two pieces to the desired position.

- Caulk a gasket of oakum about three-fourths inch thick into the bell to prevent the grout from running into the pipe.

- Mix grout, using one part Portland cement, two parts clean, sharp, washed sand, and sufficient water to thoroughly dampen.

- Fill the joint with grout, using a packing iron.

- Recaulk the joint after 30 minutes with a packing iron. You have to close shrinkage cracks that occur after the initial set of the grout.

- Smooth and bevel the grout off with a trowel. In hot weather, cover the joint with a wet burlap sack.

- Remove excess mortar with either a swab or a scraper.

Note that a regular swab, with some additional rags tied to the end to compensate for larger size pipe, is ideal for dragging through each length to remove the excess mortar.

The use of "speed seal joints" (rubber rings) in joining vitrified clay pipe has become widespread. Speed seal joints eliminate the use of oakum and mortar joints for sewer mains. This speed seal is made a part of the vitrified pipe joint when manufactured. It is made of permanent polyvinyl chloride and called a "plastisol joint connection." This type of joint helps to ensure tight joints that are rootproof, flexible, and so forth.

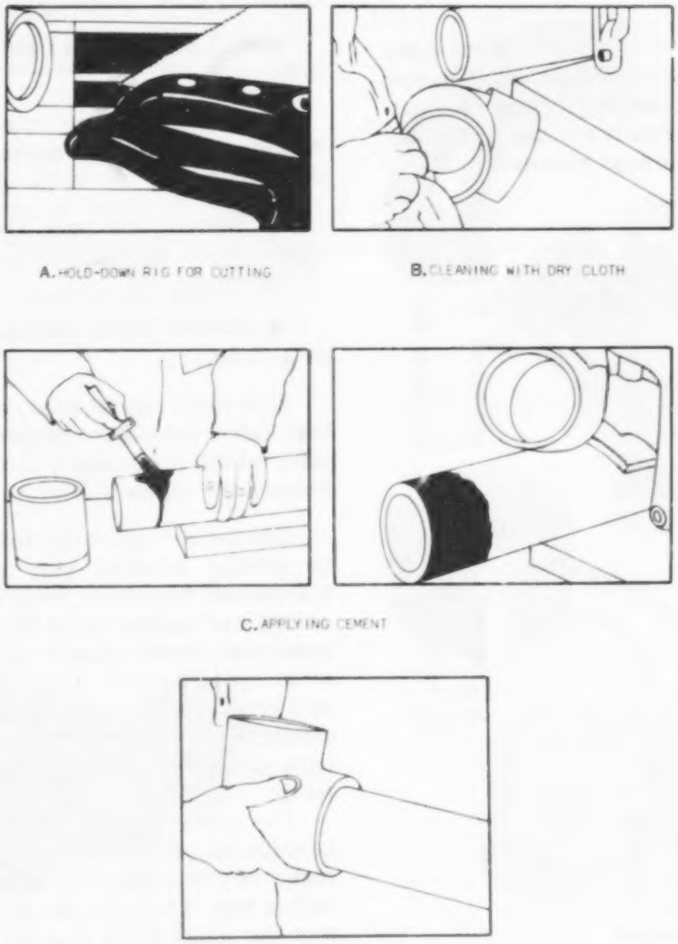
The speed seal, or mechanical seal, joint can be installed quickly and easily by one person. To make the joint, first insert the spigot end into the bell or hub. Then give the pipe a strong push so that the spigot locks into the hub seal. A solution of liquid soap may be spread on the joint to help it slip into place easily. You will find that other types of mechanical seal joints are also available. They all use about the same method of installation. Incidentally, special mechanical seal adapters are available for joining vitrified clay pipe to cast-iron soil pipe or soil pipe to vitrified pipe.

Plastic Pipe

The use of plastic pipe has expanded greatly in the last 30 years. At first, plastic was used for lawn sprinklers, farm water systems, and acid drainage from mines. Now plastic pipe is used for all kinds of applications, from shipboard installations to municipal water treatment and domestic water uses.

The advantages of plastic pipe include resistance to nearly all acids, caustics, salt solutions, and other corrosive liquids. It does not scale, pit, corrode, or rust. Bacteria does not grow well, and it is also nontoxic. Plastic pipe has very low resistance because of its smooth inner surface. Being nonconductive, it is not subject to electrolytic corrosion. Plastic pipe can be used underground in acid, alkaline, wet, or dry soil without a protective coating. It also is strong and can handle operating pressures in most moderate service processes within the temperature range of that particular material. Plastic pipe is light in comparison to metal. Finally, it can be easily joined in a wide variety of methods—solvent welding, fusion welding, fillet welding, and threading; each method has a certain advantage.

HANDLING AND STORING PLASTIC PIPE.—When unloading plastic pipe, do not drop



A. HOLD-DOWN RIG FOR CUTTING

B. CLEANING WITH DRY CLOTH

C. APPLYING CEMENT

D. JOINING

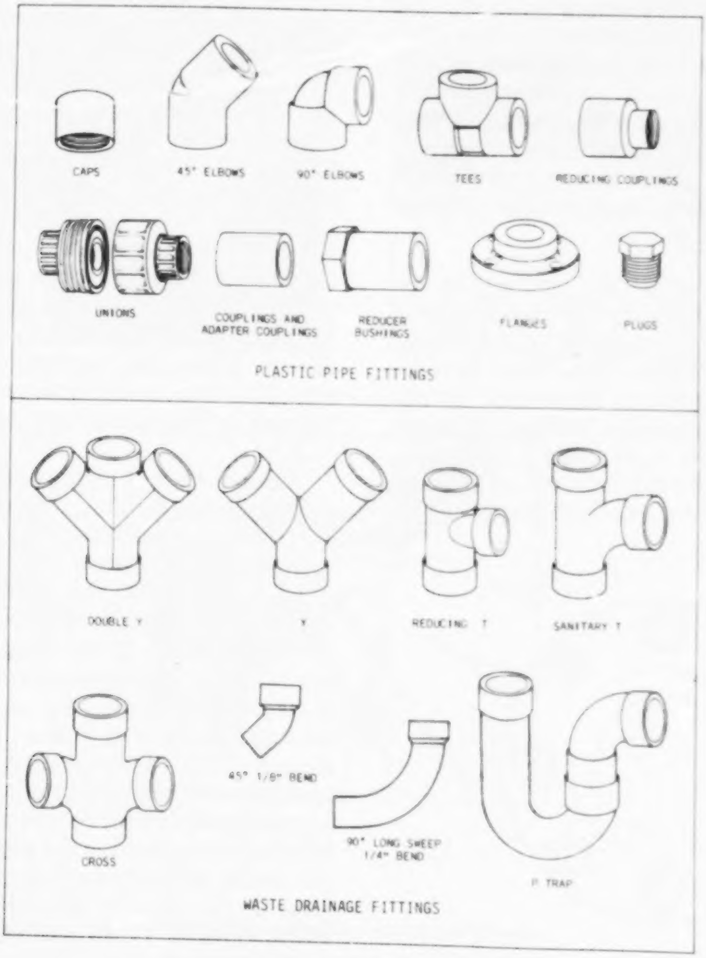
54.458

Figure 3-24.—Making cement solvent weld joints on plastic pipe.

it on the ground. Remember, scratches and gouges from dragging it on rough surfaces tend to reduce the pressure-carrying capacity. Pipe should be stored on racks to prevent sagging. Burrs and sharp edges on storage racks should be removed before storing the pipe. Plastic pipe should be stored in a shaded area away from any source of heat that could cause damage to the pipe. During prolonged storage, it should not be stacked more than 2 feet high because the weight causes it to flatten or go out of round. Before installing plastic pipe, inspect all pipe and fittings for cuts, scratches, buckling, and kinks which should be cut out.

CUTTING.—When cutting plastic pipe, use either a fine-toothed hacksaw, circular, or band saw with carbide-tipped blades. Pipe and tube cutters can be used when adapted with a blade for cutting plastic pipe. Use a miter box or hold-down rig to help cut the pipe square, as shown in view A, figure 3-24. Remove all burrs and chips from both the inside diameter (I.D.) and outside diameter (O.D.) of the pipe. The end of the pipe should be beveled to approximately one-sixteenth of an inch to three thirty-seconds of an inch at a 10-degree to 15-degree angle. This minimizes the wiping of solvent from the I.D. of the fitting as the pipe is put into the socket. You can bevel the end of the pipe with a coarse file or special beveling tool.

FITTINGS.—Plastic flanges and flanged fittings (fig. 3-25) are available in a full range of


CAPS
45° ELBOWS
90° ELBOWS
TEES
REDUCING COUPLINGS
UNIONS
COUPLINGS AND ADAPTER COUPLINGS
REDUCER BUSHINGS
FLANGES
PLUGS
PLASTIC PIPE FITTINGS
DOUBLE Y
Y
REDUCING T
SANITARY T
CROSS
45° 1/8" BEND
90° LONG SWEEP 1/4" BEND
P TRAP
WASTE DRAINAGE FITTINGS

54.459

Figure 3-25.—Plastic pipe fittings.

sizes and may be attached to the pipe by solvent welding, fillet welding, threading, or fusion welding. Soft rubber gaskets are preferred with plastic flanges. When tightening flange bolts, pull them down gradually to a uniform tightness and in a diametrical manner, as shown in figure 3-26.

JOINING.—There are four methods of joining plastic pipe: solvent welding, fusion welding, fillet welding, and threading.

Before solvent welding PVC and CPVC plastic pipe, clean the pipe and fittings, as shown in view B, figure 3-24. Use a clean, dry cloth and wipe away all loose dirt and moisture from inside the fitting and from the outside of the plastic pipe. Ensure the fittings and the pipe are of the same temperature for at least an hour before welding; this will assure they are thermally balanced. With a bristle brush, apply a coating of primer to the outside of the pipe. This removes surface gloss and etches the pipe. Do the same to the inside of the fittings. If the pipe is so hot the primer evaporates or if the pipe is above 90°F, move it to a shaded area before priming the surfaces. Use notched boards to keep the pipe ends out of the dirt. Clean the pipe ends before cement application.

Dip a brush in cement and apply it to the entire active surface of the pipe to a width slightly more than the depth of the socket of the fitting, as shown in view C, figure 3-24. Then, brush a light coating in the depth of the socket. (Avoid excess cement to eliminate the buildup inside the fitting when the pipe is socketed.) Apply the second coating of cement to the end of the pipe to ensure no "holidays" exist. (There should be no problem of too much cement on the pipe because the excess will bead out on the surface of the face of the fitting and can be easily wiped away.) Immediately, upon finishing the cement application, insert the pipe to full socket depth and rotate one fourth of a turn to ensure complete distribution of cement, as shown in view D, figure 3-24. Hold the pipe together for 10 to 15 seconds so it does not move out of its socket. After joining, immediately wipe the excess cement from the pipe and fitting and gently set the pipe on a level surface. Do NOT move the pipe for about 2 minutes. (As the pipe size increases, it takes longer for the joint to set up.) The pipe SHOULD NOT be joined in temperatures below 40°F and above 90°F or when it is exposed to direct sunlight. The drying time should be at least 48 hours before the joint is moved or subjected to internal or external pressure. The drying time is shorter in hot weather and longer in colder weather. **DO NOT ATTEMPT TO SPEED THE SETTING OR DRYING OF THE CEMENT BY APPLYING HEAT TO SOLVENT-WELDED JOINTS.** Forced rapid drying by applying heat causes cement solvent to boil off, forming bubbles and blisters in the cement film. During cool weather, the setting of the cement can be speeded by prewarming the cement, pipe, and fitting, or by shielding the joint from the wind. **CHECK THE SHELF LIFE OF THE CEMENT.** Do NOT use cement that is lumpy or stringy. Do NOT try to thin it out with a thinner or primer. Always follow the instructions on the cement container; the above estimates should in no way be used in the place of application instructions.

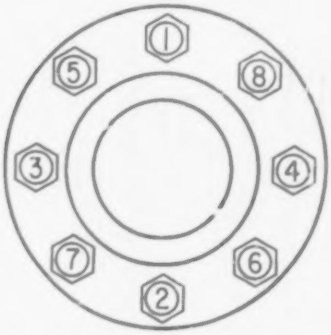


Figure 3-26.—Diametric order of tightening flange bolts.

Fusion welding requires either a gas- or an electric-heated welding tool, as shown in figure 3-27. As the tool warms up, spray its contact surfaces lightly with a silicone-releasing agent (view A, fig. 3-27). This prevents the pipe from sticking to the surface of the welding tool. Check the temperature of the tool. Ensure the tool reaches the proper temperature range (view B, fig. 3-27) before placing the pipe on the heating element. Be sure the pipe is squarely on the element. Hold onto the pipe, as shown in view C, figure 3-27, until a bead appears on the pipe at the entrance of the female tool piece. After the bead appears, remove the pipe and insert it into the fitting, squarely and completely, as shown in view D, figure 3-27. **DO NOT ROTATE THE PIPE WHILE IT IS BEING JOINED WITH THE FITTING.** After joining, clean the fusion welding tool, as shown in view E, figure 3-27.

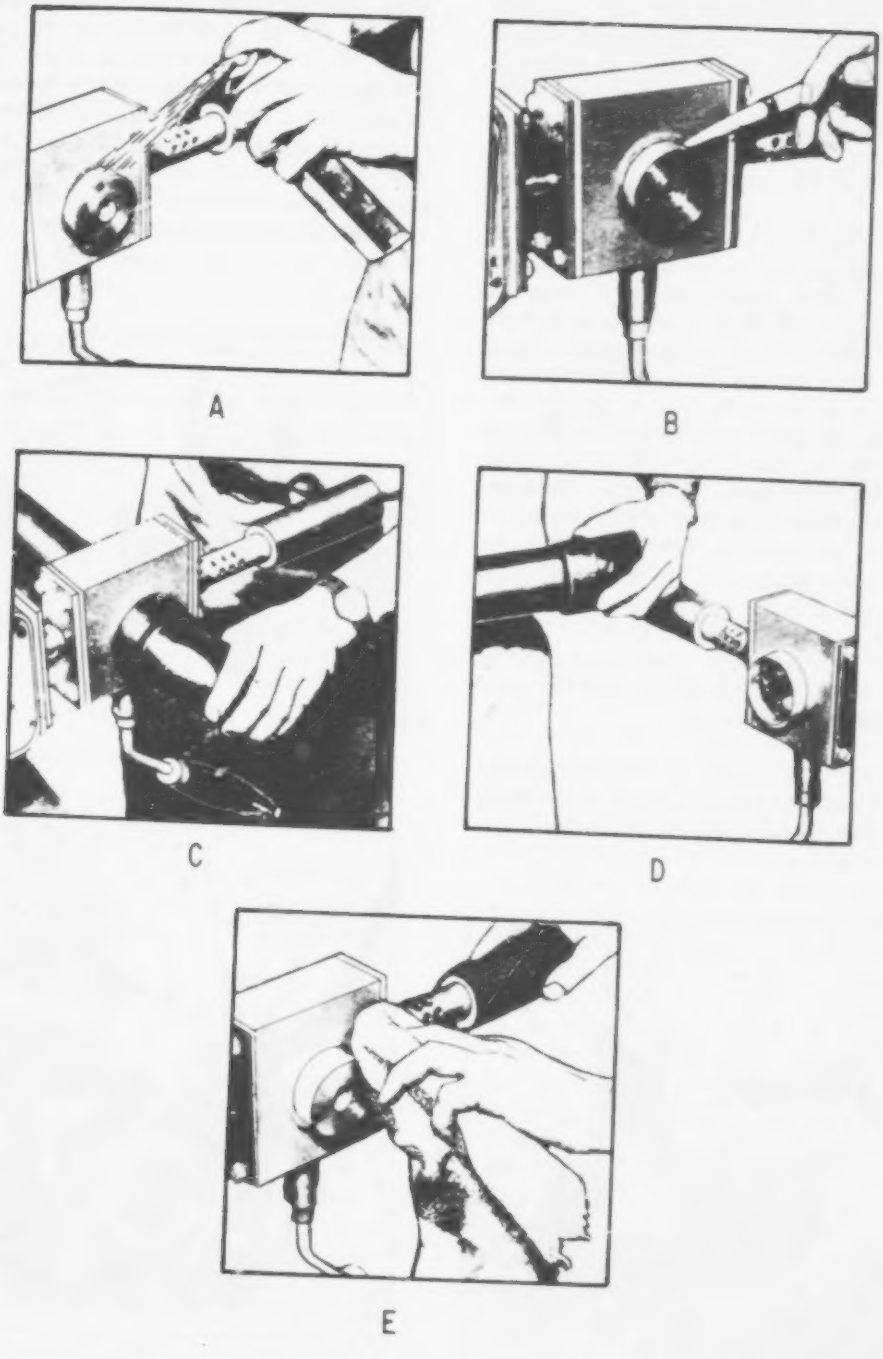


Figure 3-27.—Fusion welding plastic pipe. 54.460

In fillet welding plastic pipe, as shown in figure 3-28, maintain uniform heat and pressure on the rod while welding. Too much pressure on the rod stretches the bead and causes the weld to crack as it cools. The rod should be held at a 90-degree angle to the joint. The rod bends in an arc when proper pressure is applied. When finishing a weld, make the bead overlap the top, NOT alongside itself, for at least three-eighths to one-half inch. Never overlap alongside when welds are being spliced.

Threaded plastic pipe should be used only as a temporary piping system. Threading reduces the wall thickness and results in lower pressure ratings. Only schedule 80 or heavier pipe should be used when plastic pipe is being threaded. Never use pipe wrenches to tighten threaded pipe; use a strap wrench, as shown in view A, figure 3-29. Be sure to use an insert within the vise jaws to prevent scoring of the pipe. Use a wood or aluminum plug while the pipe is being threaded to prevent distortion of the pipe and to avoid off-center threads, as shown in view B, figure 3-29. The dies should be sharp; and for best results with power tools, use a 5-degree negative front rake. When tightening threaded joints, avoid too much torque. One or two turns past hand-tight is sufficient. Teflon tape should be used for pipe joint compound or pipe dope.

SNAKING.—On hot days, after the plastic pipe has been cement solvent welded, it is a good idea to snake the pipe beside the ditch (or if the ditch is wide enough, in the ditch) during its required drying time. **DO NOT APPLY STRESS AND DISTURB THE UNDRIED JOINT.** Snaking gives added length to the pipeline to compensate for thermal contraction as the pipe cools. When the temperature change is less than 30°F, snaking is not necessary. When cement solvent welding on a hot, summer day during the late afternoon, be sure to snake the line. Since the pipe dries during the cool of the night, the thermal contraction of the pipe could stress the joint and pull the undried cement apart. See table 3-1 for a

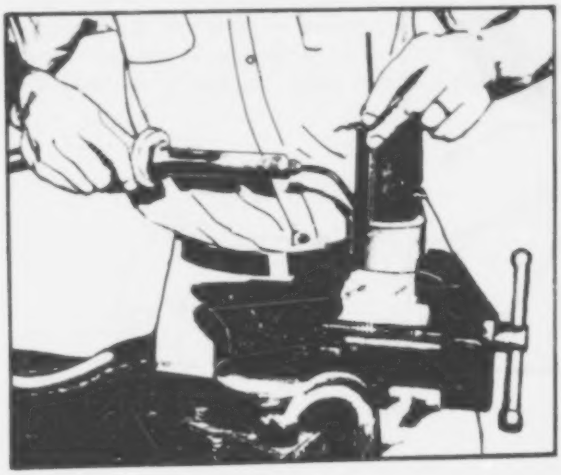


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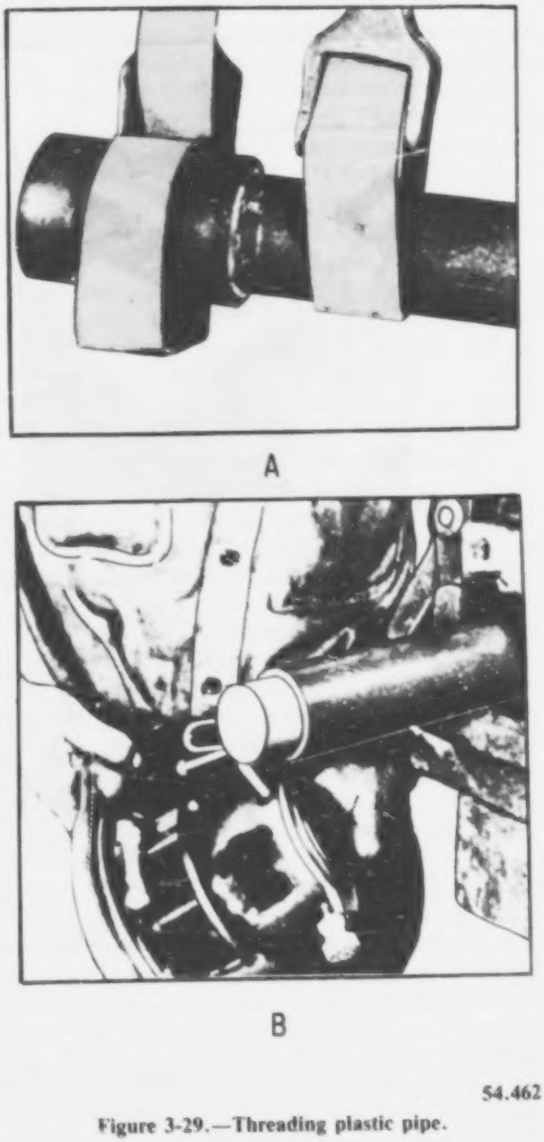
Figure 3-28.—Fillet welding plastic pipe.



54.462

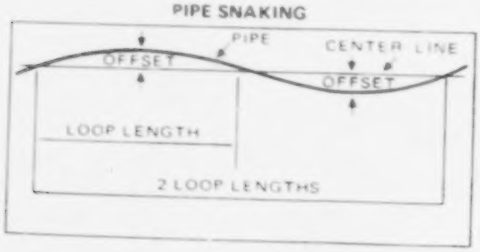
Figure 3-29.—Threading plastic pipe.

general guideline on "loop" dimensions for various lengths of line and temperature ranges.

TESTING.—Testing should be done in two intervals.

1. The initial test should be a low-pressure hydrostatic test (air or gas is NOT recommended). This test should never exceed 50 pounds per square inch gauge (psig). When testing with a gauge, allow the pipe to remain under pressure for a few hours; then check to see if there is a pressure drop. If the pressure drops, there is a leak. The pipeline should then be walked and closely inspected, checking each joint closely. After locating the leak, repair it, and pressurize again using LOW pressure.
2. After completion of the low-pressure test, place the pipeline in the trench (if not tested in ditch) and backfill, leaving the joints exposed. The pipe should be uniformly and constantly supported its entire length. **DO NOT SUPPORT WITH BLOCKS.** The high-pressure test should be conducted at 1 1/2 times the working pressure and be held for at least 12 hours. Leaks found on the pipe itself should be cut out completely and replaced by using fittings (couplings). Backfill in the early morning during hot weather. The pipe should be covered 6 to 8 inches with backfill that is free of rocks and debris. It is advisable to maintain a pressure of 15 to 20 psig on the pipeline while backfilling to keep from damaging it. Anchors, valves, boxes, and so forth, should be supported separately to prevent additional stress or bending from the pipe. Piping, under roadways or railroads, should be done with sleeving (metal or concrete). The pipe should be isolated from direct contact with the concrete. When concrete anchors are being poured, wrap the pipe with rubber or other protective material. If the anchor is for axial movement, use the solvent welding process to weld a split collar to the pipe that provides the needed protection. When solvent welding collars on the pipe, allow 48 hours for drying time before pouring concrete.

Table 3-1.—Pipe Snaking Loop Offset



Loop Offset in Inches for Contraction

	Max. Temperature Variation, °F, Between Time of Solvent Welding and Final Use				
Loop Length	10°	20°	30°	40°	50°
20 Feet	3"	4"	5"	5"	6"
50 Feet	7"	9"	11"	13"	14"
100 Feet	13"	18"	22"	26"	29"
Loop Length	60°	70°	80°	90°	100°
20 Feet	6"	7"	7"	8"	8"
50 Feet	16"	17"	18"	19"	20"
100 Feet	32"	35"	37"	40"	42"

RISERS.—Never expect plastic pipe to support aboveground valves or fixtures. The valves or fixtures MUST be provided with their own support, because the risers cannot support heavy fittings or fixtures.

Laying Sewer Pipes

Small pipes can be assembled and joined in sections on top of the ground and laid in the trench by hand. Large, heavy pipes are usually laid in the trench and then joined. These pipes may be lowered into the trench by rope, cable, or chain. Larger pipe may require the use of machinery operated by an Equipment Operator.

When assembling and joining pipes outside the trench, make sure you are a safe distance from the edge of the trench to prevent cave-ins. Also, do not leave tools or materials near the edge of a trench where they may be knocked off and injure someone working in the trench, or cause a worker to lose his or her footing and fall into the trench.

Sewer pipes should be laid on a compacted bed of sand, gravel, or material taken from the trench excavation, if suitable, to provide a slightly yielding and uniform bearing. This step assures safe support for the pipe, fill, and surface loads. When pipes are laid on sand, gravel, or similar material, the weight of the pipe usually provides a suitable equalizing bed.

Pipelines should be embedded carefully, so they do not settle at any point. Settling causes suspended matter to collect in the lower portion of the pipe, restricting the flow and reducing the capacity of the line.

Checking Grade of Sewer Lines

After you have laid the pipes, your next step is to check the grade and align the pipeline. This is very important in installing an underground sewer system. Remember, sewage does not flow uphill. The pipe is laid with the hub end upstream, and the laying proceeds upgrade. The spigot is inserted into the hub of the previously laid length. Each length is checked as to its grade and alignment before the next length is placed.

When you are grading for the proper pitch per foot, the method shown in figure 3-30 may be used as a guide. This figure shows a ditch with batter boards used in transferring line and grade to trench; also, a stick for checking grade is shown in position.

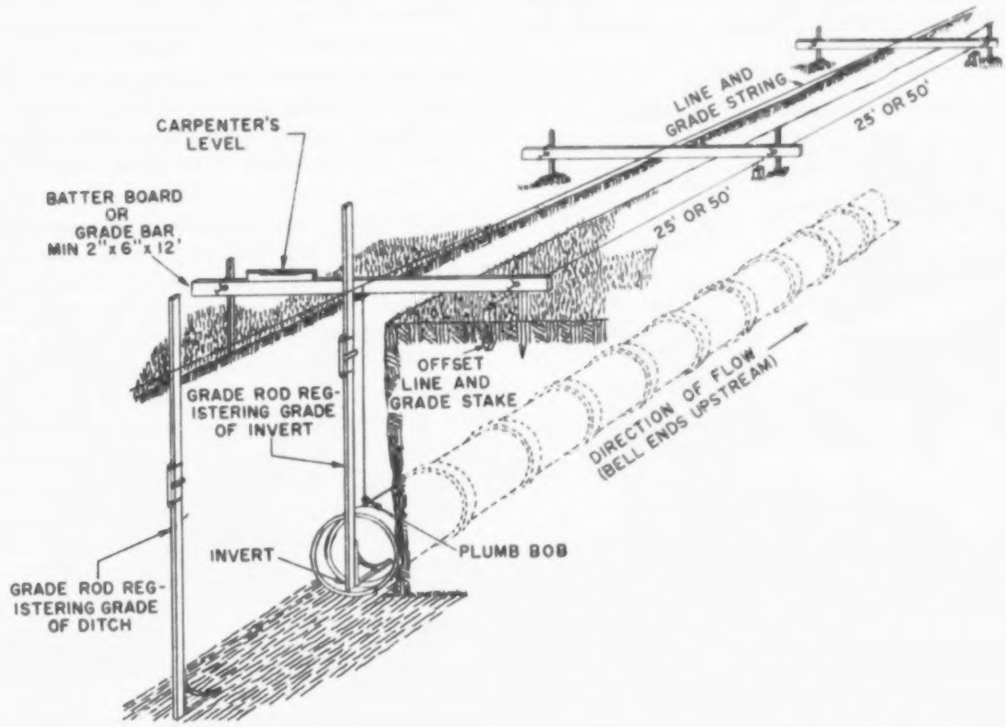
An Engineering Aid (EA) is responsible for setting the batter boards at the proper level for the job at hand. Batter boards are placed across the trench at about 25- to 50-foot intervals. Elevations are run by an EA, and a mark is placed on the stakes at some even foot distance above the invert (which is the lowest point on the inside of the pipe) of the sewer. A nail is then driven in the top of the batter boards, and a cord is stretched from board to board. The center line for the pipe is then transferred from the cord to the bottom of the trench by means of a plumb bob. Grade is transferred by means of a stick, marked in even foot marks, having a short piece fastened at a right angle to its lower end. Grade is checked by placing the short piece on the invert of each length of sewer pipe and aligning the proper mark on the grade rod to the cord.

Testing

After the roughing in is completed, test and inspect all the pipes for leaks. The purpose of testing the pipeline is to make sure the joints are tight enough to withstand working pressure. Since sewer line of this type is of gravity drainage, the test procedures are different than those described later under the heading of "Water Service."

Before the pipe is covered with dirt, it must be tested for leakage. There are several methods of effecting this test. The most widely used test is the water test, although an air test or odor test may be used.

WATER TEST.—Here are the main steps in making a water test. At the lowest point of the


CARPENTER'S LEVEL
BATTER BOARD OR GRADE BAR MIN 2"x6"x12'
LINE AND GRADE STRING
25' OR 50'
25' OR 50'
OFFSET LINE AND GRADE STAKE
GRADE ROD REGISTERING GRADE OF INVERT
DIRECTION OF FLOW (BELL ENDS UPSTREAM)
INVERT
PLUMB BOB
GRADE ROD REGISTERING GRADE OF DITCH

54.23

Figure 3-30.—Laying sewer pipe to line and grade.

section to be tested, insert a test plug in the open end of the pipe or a test tee, like those shown in figure 3-31, and plug other openings. Fill the pipe to its highest level with water; about a 10-foot head is enough. Leave the water in the pipe for at least 15 minutes before starting the test. This allows the oakum to soak up some water before you look for leaks. If necessary, refill the pipe to overflow and check each joint for leaks.

AIR TEST.—Before making an air test, fill the system with water and allow it to stand until the oakum expands at the joints. Drain the water from the lines and reinsert the test plug. Close all openings and apply air pressure of at least 5 pounds per square inch (psi). In a satisfactory test, the line should hold 5 pounds psi for 15 minutes. If it does not, cover the joints with a soapy water solution and check for bubbles at the leak.

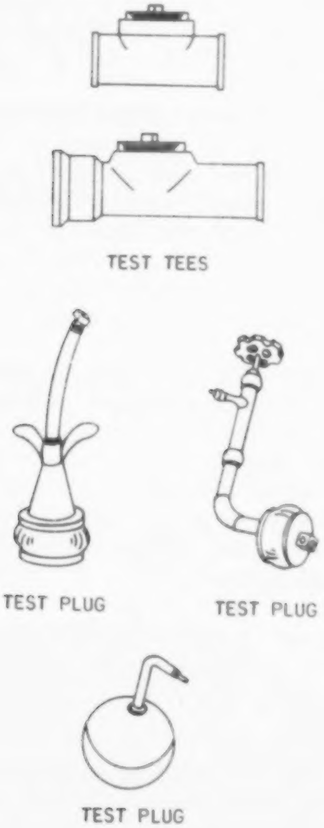
ODOR TEST.—Before making an odor test, plug all openings in the sewer and the branches. After sealing the openings, pour 2 ounces of oil of peppermint in each line or stack. Then pour approximately 1 gallon of boiling water in the stack and seal it. The odor of peppermint at any point in the installation indicates a leak. The inspector, checking the installation for leaks, should not be near the oil of peppermint at any time before the inspection. Such exposure rapidly dulls his or her sensitivity to the odor of peppermint. The peppermint test is not as conclusive as the water and air tests described above, since no pressure is on the pipe.

NOTE: Repeat tests as necessary until all the leaks are found and repaired.

Where a system of pipelines has been installed using gaskets, test one floor at a time. Should there be more than one floor to be tested, be sure all bends, changes of direction, and ends of runs are restrained (limited).

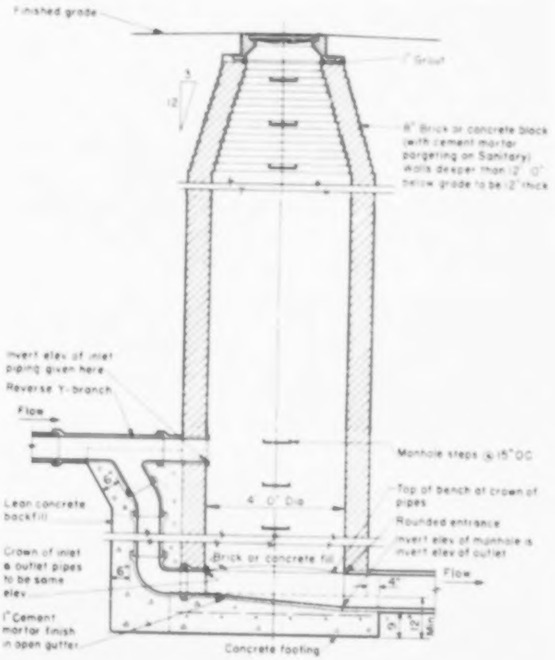
Manholes

Under normal conditions it is not your responsibility as a Utilitiesman to construct manholes. They are made of concrete or brick. However, you may be working with the Builders in spotting the location for the manholes. Figure 3-32 shows a typical drop manhole.


TEST TEES
TEST PLUG
TEST PLUG
TEST PLUG

54.463

Figure 3-31.—Test plugs and test tees.


Finished grade
1" Grout
3
12
8" Brick or concrete block (with cement mortar pargeting on Sanitary) walls deeper than 12'-0" below grade to be 12" thick
Invert elev of inlet piping given here
Reverse Y-branch
Flow
Manhole steps @ 15" OC
6"
Lean concrete backfill
4'-0" Dia
Top of bench at crown of pipes
Rounded entrance
Invert elev of manhole is invert elev of outlet
Brick or concrete fill
Crown of inlet & outlet pipes to be same elev
6"
Flow
4"
1" Cement mortar finish in open gutter
Concrete footing
6
12
3

54.36

Figure 3-32.—Standard drop manhole for sanitary and drainage system.

Watertight manholes are made of brick or concrete, 4 feet in diameter at sewer level, and should be placed at junctions and bends in the line. They are spaced preferably 300 feet apart for 8-inch pipe, 400 feet apart for 10- to 15-inch pipe, 500 feet apart for 18- to 48-inch pipe, and 600 feet apart for larger sizes. Sewers should be laid straight to line and grade between manholes, and any change in the size of sewer lines must take place only at the manholes. The crown of the outlet pipe from a manhole should be on a line with or below the crown of the inlet pipe. When the invert of the inlet pipe is more than 2 feet above that of the outlet pipe, a drop manhole must be provided to conduct the sewage to a lower level with minimum turbulence.

Backfilling and Tamping

After all pipelines have been laid and tested, they are ready to be covered; this process is known as backfilling and tamping. The method described below should work for sewer lines.

Fine material, free from stones and other debris, is tamped in uniform layers with a small hand- or air-operated tamper under, around, and over the pipe. Use a hand shovel to backfill the ditch until the pipe has a 2-foot covering. This fill should be placed in the ditch and tamped in 4-inch layers or less. It should proceed evenly on each side of the pipe, so injurious side pressure cannot occur. Make sure you do NOT walk on the pipe until you have at least 1 foot of soil tamped over the pipe. Until 2 feet of fill has been placed over the pipe, the filling should be done carefully with hand shovels; after that, machinery may be used for faster backfilling. However, do not let the machinery run over the line.

Puddling, or flooding, with water to consolidate the backfill should NOT be done for a sewer line. The sections of pipe are in short lengths and tend to settle very rapidly to form pockets or low spots in the line.

ABOVEGROUND SEWAGE PIPING

After installing the underground piping, the next phase in the installation of a sewer system is to install the aboveground piping. Information on materials applicable to installing aboveground sewage piping is given in the following sections. Installation procedures are the same for aboveground and underground sewer pipe.

Types of Pipes

A number of different types of pipes are used in the aboveground and interior parts of a plumbing system. Some of the common types of pipes with which you should be familiar are discussed briefly below.

While GALVANIZED WROUGHT-IRON PIPE is an excellent material for aboveground plumbing, it is costly. It is available in lengths from 18 to 22 feet. Galvanized wrought-iron pipe is constructed of wrought iron dipped in molten zinc to protect it from corrosion and provide high resistance to acid waste.

ACID-RESISTANT CAST-IRON PIPE is composed of an alloy of cast iron and silicon. It is used to serve chemical laboratories and other installations through which acid waste flows. In handling acid-resistant pipe, such as Durion, be careful because it is very brittle and cracks easily. It is cast in 5-foot lengths and comes in single and double hubs.

BRASS PIPE consists of an alloy of zinc and copper. Brass pipe has a smooth interior and can resist most acids; however, it is expensive. It is available in 20-foot lengths; because it tends to bend, it must be supported at intervals of 8 to 10 feet.

LEAD or LEAD-LINED STEEL PIPE is sometimes used to carry distilled water for batteries. However, tin-lined, block tin, glass, or some types of plastic pipe must be used where no impurities are acceptable. Because it bends easily, lead pipe must be well supported. It is available in three weights: (1) standard, (2) common, and (3) extra heavy. The standard weight is commonly used.

COPPER PIPE is suitable for use in waste, vent, and water installations. Remember that ammonia and water corrode copper and bronze lines. Also, when copper is used for waste pipe installations, always make sure it is rigid to overcome sagging. You can obtain the pipe in convenient lengths, then cut it to the size needed for the job at hand.

PLASTIC PIPE is also suitable for use aboveground for sewage, venting, and water.

Roughing In

The term *roughing in* refers to the installation of all parts of the plumbing system that can be completed before the installation of fixtures, such as the drainage, water supply, vent piping, and fixture supports. After completing the roughing in, test the plumbing before you conceal the roughing in. Make sure all points are free of sewer gas and watertight.

Traps

A number of different types of traps are available. However, the trap used with plumbing fixtures is normally the P-trap. (See fig. 3-33.) Traps are part of plumbing because they prevent sewer gases from entering a building and causing serious illness or death.

The term *trap seal* refers to the water held in the bent portion of a fixture trap. (See fig. 3-33.) True to its name, the trap seal forms a seal against the passage of sewer gases through the trap and into the building. The most frequently used seal trap has a depth of 2 inches between the overflow and the dip. The deep seal trap has a depth of 4 inches.

The P-trap got its name because its general shape is that of the letter *P*. It comes in sizes from 1 1/4 to 6 inches in diameter. Various types of P-traps are available, so designs may differ from one manufacturer to another. The P-trap is usually made of nickel or chrome-plated brass, malleable galvanized, cast iron, other metal alloys, and plastic.

The P-trap is used for fixtures suspended from the walls or supported on pedestals; for instance, lavatories, sinks, and urinals. At times, the P-trap may also be suitable in shower baths and installations that do not require wasting of large amounts of water.

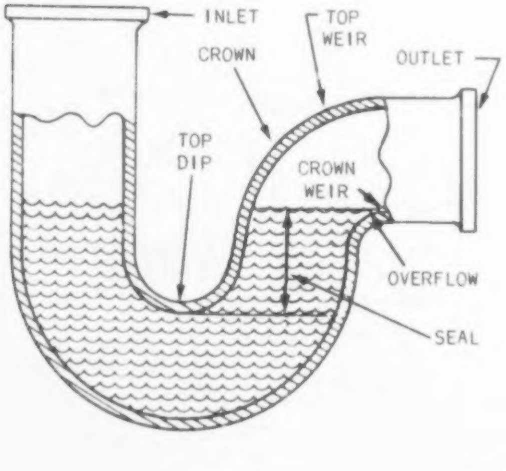


Figure 3-33.—P-trap.

When using a P-trap for fixtures suspended from the wall, you should install it as close to the fixture as possible. Be careful not to install a vertical leg that is too long between the trap and the fixture proper. It is also important for the horizontal leg connection to the waste system to be short for ventilation purposes.

Vents

To prevent the siphonage of a trap seal in fixture traps, you introduce air from outside the building to the outlet (or discharge) end of the trap. The air is supplied through pipes or VENTS. This air provides pressure on the outlet end of the seal equal to pressure on the inlet end.

Atmospheric pressure at sea level is about 14.7 pounds per square inch. This pressure remains virtually constant on the inlet end of the water seal. Obviously, a greater or lesser amount of pressure on the outlet end of the trap seal forces the water in the direction of least resistance. Since the air supplied by the vent to the outlet end provides a pressure equal to that at the inlet end of the trap, the trap seal cannot escape through siphonage.

All vent systems should be provided with a main vent or vent stack and a main soil and waste vent. A MAIN VENT may be defined as the principal artery of the venting system, and vent branches may be connected to the main vent and run undiminished in size as directly as possible from the building drain to the open air above the roof. The MAIN SOIL AND WASTE STACK, as indicated in figure 3-7, is installed in a vertical position.

The term *main soil* and *waste vent*, or *soil stack vent*, refers to the portion of the stack extending above the highest fixture branch. In figure 3-7, this vent extends through the roof. Actually, it is an extension of the main soil and waste stack.

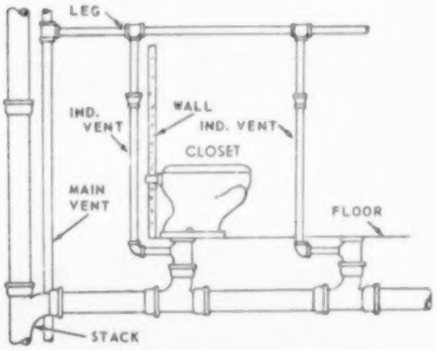
COMMON TYPES OF VENTS.—Various types of vents are used in the ventilation of fixtures; even in the best of installations, you may find several different types of vents. The selection of a particular type of vent depends largely on the manner in which the plumbing fixtures are located and grouped. Some of the common types of vents which you may use frequently in your work are mentioned briefly below.

A INDIVIDUAL VENT, also known as a BACK VENT, is a vent that connects the main vent with the individual trap underneath or behind a fixture. This method of venting is shown in figure 3-34. When you install two or more fixtures on the individual vent basis, ensure the leg (see illustration) connecting the individual vents to the main vent is large enough to carry the total load.

A COMMON VENT vents two traps to a single vent pipe, as shown in figure 3-35. The unit vent can be used when a pair of lavatories are installed side by side, as well as when they are hung back to back on either side of a partition (as shown in the illustration). A point to note is that the waste from both fixtures discharges into a double sanitary tee.

A CIRCUIT VENT serves a group of fixtures. As shown in figure 3-36, a circuit vent extends from the main vent to a position on the horizontal branch between the last two fixture connections. Make sure that a maximum of eight fixtures are put on any one circuit. If you have more than eight fixtures to be circuit vented, use two circuits instead of one. In this type of vent, water and waste discharged by the last fixture tends to scour the vents of other fixtures on the line.

A vent pipe, in which liquid wastes flow through a portion of it, is known as a WET VENT. A LOOP VENT is the same, except that it connects into the stack unit to form a loop. This type of vent may be used on a small group of bathroom fixtures, such as a lavatory, water closet, and shower, as shown in figure 3-37. The pipe for a wet vent installation should be sized to take care of the lavatory, water closet, and shower.



54.39

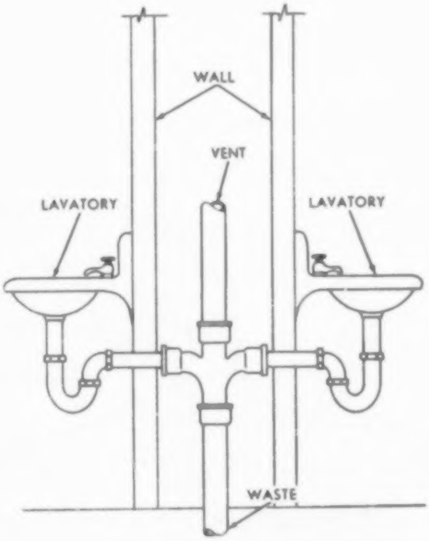
Figure 3-34.—Individual (or back) venting.

NOTE: When you are draining more than four fixture units, the wet vent should never be under 2 inches in diameter. A water closet must not drain into a wet vent.

As indicated in the figure 3-37, the lavatory should be individually vented. This is necessary to prevent loss of the trap seal through indirect siphonage. Another point to note with the lavatory is that the relatively clean water discharged from it tends to scour the wet vent, preventing an excessive buildup of waste material in the vent.

INSTALLATION POINTERS.—A venting system must be properly installed with little repair and upkeep. This section points out your duties in installing vent systems.

Refer to figure 3-38. Notice that a MAIN VENT TEE forms a junction between the main vent and the main soil and waste vent. This is a tapped tee having a stack side outlet. It should be installed by caulking in the vertical stack, at least 6 inches above the overflow level of the highest fixture connected. After this has been done, the vertical stack should be extended, full size or larger, through the roof to form the vent terminal. The pipe must extend at least 6 inches above the roof. If the roof is used for other than weather protection, the vent terminal must be



54.40

Figure 3-35.—Two fixtures unit vented.

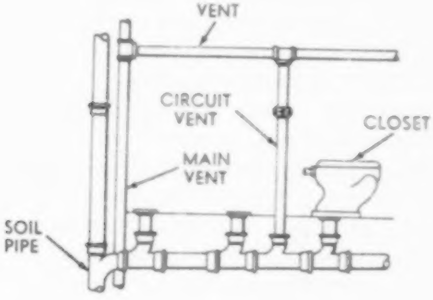
7 feet above the roof. The opening in the roof through which the main soil and waste vent runs must be properly waterproofed. Roof flashing is used for this purpose. Roof flashing is made of galvanized iron, or copper. Flashing is available in different sizes. Normally, the size of flashing needed for a job is determined by the size of the main soil and waste vent.

When installing roof flashing on a shingled roof, extend it under two courses of shingles above the pipe. On a flat roof, place it between layers of the roofing material and have the finishing layer over the top of the flashing. To complete the installation on either type of roof, always apply a coat of roofing cement as added protection against leakage.

In a cold climate, you must think about ways to prevent closure of the main soil and waste vent at the roof outlet by freezing. The air discharged by the main stack and waste vent is humid and condenses. This condensation freezes when exposed to extremely low temperatures.

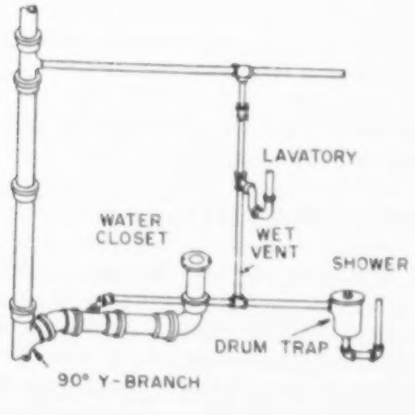
One way to prevent freezing is to increase the pipe to a size or two larger than the vertical vent passing through the roof. Or, install high-lead flashing to provide an insulating pocket of air between the flashing and the end of the main soil and waste vent above the roof. Being open to the heat of the building, the air pocket allows an intermediate warming area for gases leaving the main soil and waste vent.

Materials used in vent piping ordinarily include galvanized pipe, cast-iron soil pipe, and at times, brass, copper, and plastic piping. Asbestos-cement pipe can also be used for venting soil and waste pipe. A single length of this pipe is often sufficient for venting a stack. For such an installation, pipe is available with a


VENT
CIRCUIT VENT
CLOSET
MAIN VENT
SOIL PIPE

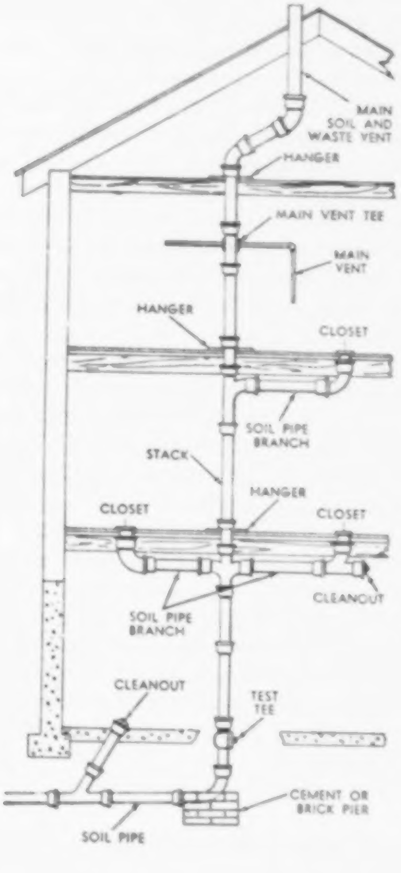
54.41

Figure 3-36.—Water closets circuit vented.


LAVATORY
WATER CLOSET
WET VENT
SHOWER
DRUM TRAP
90° Y-BRANCH

54.42

Figure 3-37.—Wet vent.


MAIN SOIL AND WASTE VENT
HANGER
MAIN VENT TEE
MAIN VENT
HANGER
CLOSET
SOIL PIPE BRANCH
STACK
HANGER
CLOSET
CLOSET
CLEANOUT
SOIL PIPE BRANCH
CLEANOUT
TEST TEE
CEMENT OR BRICK PIER
SOIL PIPE

54.44

Figure 3-38.—Soil pipe branches.

machined end. This end is placed in the bell of the soil or waste pipe, and the connection is made by yarning, leading, and caulking.

In all phases of the venting system, do your best to use proper-sized piping. Remember, the diameter of the vent stack or main vent must not be less than 2 inches. The actual diameter depends on the developed length of the vent stack and on the number of fixture units installed on the soil or waste stack. The diameter of a stack vent should be at least as large as that of the soil or waste stack.

Soil and waste pipe BRANCHES are horizontal branch takeoffs that connect various fixtures and the vertical stack. (See fig. 3-38.) One method of installing a branch takeoff from the vertical stack is to use a Y-branch with a 1/8 bend caulked into it. Another method is to use a sanitary tee, which is an extra short pattern 90-degree Y-branch. Of these two methods, the sanitary tee is better because with the sanitary tee you eliminate one fitting and an extra caulked joint; both are required for the 1/8 bend takeoff. Some local codes allow you to connect more fixture units to a given size of stack when a combination Y and 1/8 bend is used. The combination Y and 1/8 bend may be more desirable than the sanitary tee. Once either fitting is caulked into place, the horizontal branch can be extended as necessary with lengths of soil pipe. They too are joined by caulking.

Waste pipes should be graded downward to ensure complete drainage. Horizontal vents should be slightly pitched to facilitate drainage of condensation.

In this chapter, only the basic types of vents and where they are used have been covered. However, there are many forms of ventilation that can be applied to a plumbing installation. The types used on a project are determined largely by the manner in which the plumbing fixtures are to be installed and where they are located.

As plumbers know, the subject of vents is the science of plumbing. Anyone can try to install piping for a plumbing system. However, if the system cannot carry waste away, the would-be plumber and the system are useless. Venting is the name of the game. For more information on venting, consult the *National Standard Plumbing Code-Illustrated*.

WATER SERVICE

The water-supply system for a building consists of the service pipe, distributing pipes, and connecting pipes, as well as fittings and control valves. Water carried by the system must meet accepted standards of purity. Two major functions of a water distribution system are (1) to carry potable water for domestic use and (2) to provide high rates of flow for fire fighting.

TRENCHING

The method of trenching for waterlines is similar to that described earlier for sewer lines. In trenching for waterlines, though, it is not necessary to set batter boards since great care is not required in laying water pipes to grade as the water is under pressure. The pipes in a waterline may follow the contour of the earth's surface in a trench at least 2 feet deep. This should, however, be the minimum depth in which they are installed. Minimum depth of the ditch depends upon the depth of the frost line in the area. The trench should be wide enough to permit ease of working around the pipes and to allow earth to be placed during backfilling. Usually, the trench will not be deep enough to require bracing.

Locate the trench at least 4 feet from a previously dug ditch, or trench, to help prevent cave-ins. Water pipes should be laid 1 foot above and 10 feet away from nearby sewers. This helps prevent the water distribution system from becoming polluted by leaks. Sometimes the water main and sewer lines may cross each other. In such cases, the water pipe must cross over the top of the sewer line, so be careful to make all joints tight. However, check the local specifications before installing them in this manner.

The distribution system must be kept free from pollution caused by leaks, back siphonage from faulty plumbing, and cross-connections. The greatest hazard in the distribution system is the cross-connection. This is a physical connection to another and unsafe or doubtful source of water, or a condition that will permit wastewater to enter the potable public supply.

LAYING WATER PIPES

An important phase in the installation of a water system is laying the underground water service pipes. Information to aid you in laying these pipes is given below.

Regardless of the pipe material used, sharp bends and dead ends should be anchored by rodding, or concrete anchors. Where the pipe is setting in saddles, metal straps may be used. Even though the pipe is installed within a ditch, the straps help support and hold the pipe in place.

Pipe should be founded on solid trench bottoms. Automatic air-release and vacuum valves should be installed at prominent peaks on long supply mains to permit escape of air while the pipe is being filled and entrance of air when it is being drained. Elsewhere in the distribution system, air normally can be released and taken in through service lines.

Flow in water pipes may be achieved by gravity with an elevated tank, or by a pumping system. Where pipe must be placed in a sloping trench, the slope should be as even as possible to keep the pipe from bending and breaking. After the trench is dug, lay your pipe and fittings alongside it. Before you start placing the pipe, shut off the water in the main supply line. The placing should start at the main supply tee.

PIPING MATERIALS AND EQUIPMENT

Piping materials used in water-supply systems include cast-iron pressure pipe, galvanized wrought iron, steel, copper, plastic, and asbestos-cement. Some of the main characteristics of pipe made from these materials and the equipment used are presented below.

Cast-Iron Pressure Pipe (For Water Mains)

The cast-iron pipe for water distribution systems is somewhat different from that used for waste systems. Some of the major differences are in the length of the pipe, joints, and lining. Cast-iron soil pipe for waste, as you know, comes in 5-foot and 10-foot lengths. Cast-iron pressure pipe for water mains comes in 20-foot lengths with either bell-and-spigot or mechanical (gland-type) joints. This pipe may be coated with coal-tar pitch or be cement-lined; however, uncoated pipe is available if needed for other purposes.

MEASURING AND CUTTING.—Cast-iron pressure pipe is measured by the inside diameter; a ruler or tape is frequently used for measuring. With a cement lining, the lining goes beyond the inside diameter of the pipe, so you have to allow for this reduced inside dimension.

To cut cast-iron water pipe to the desired length, use either a hand-operated chain cutter or a power hacksaw. Because of the construction of this pipe, it does not need reaming after cutting; but, you can use a file to dress down the cut when necessary.

FITTINGS.—Three major types of fittings for joining cast-iron pipes in water service are tees, elbows, and couplings. Since these fittings look like those used for sewer lines, a detailed description need not be given here.

JOINING.—In water service lines, bell-and-spigot cast-iron pipe is joined with lead, lead wool, or sometimes a sulfur compound. Specially prepared treated paper also may be used.

Before making a joint, you should first check each length of pipe for cracks, or splits. After eyeing for defects, rap the pipe with a hammer. With a little experience, you will pick up the difference between a good pipe and a bad pipe.

Next, wrap the yarn around the spigot end, place it in the bell of the previously laid length, then straighten and adjust it with a yarning iron. Use enough yarn to fill the joint within approximately 2 inches of the face of the bell. Then, clamp a joint runner in place around the joint so that it fits tightly against the outer edge of the bell. The lead is then poured into the V-shaped opening left at the top by the clamped joint runner. This lead fills the space between the yarn and the runner. This joint must be made in one pouring for best results. After the lead has hardened (about 10 seconds), the runner is removed, and the lead, which shrinks while cooling, is expanded by caulking until it makes a tight fit. Caulking requires skill; hammer blows that are too heavy could split the bell, or blows too light could leave the joint loose.

Lead wool is lead in a shredded form that does not require melting. Lead wool is sometimes used when water is encountered in the trench. In this process, more yarn is used; the joint is filled to about 1 inch of the face of the bell. Lead wool requires more time in caulking than poured lead.

A sulfur compound is melted on the job, like lead, but at a lower temperature. It is then poured into a joint prepared for a cast-lead joint. The fact that it is light in weight is its primary advantage. It requires no caulking and provides a strong joint that is not likely to blow out. Initially, joints of sulfur compounds leak or sweat slightly, but they tighten up in a short time. Since the joints are rigid, they should not be used to connect a newly laid line to an old one, as the settlement of the new line causes a crack. A lead joint should be used at the connection.

Mechanical joints are made with rubber sealing rings held in place by metal follower rings bolted to the pipe. This type of joint is designed to permit expansion and contraction of the pipe without injury to the joints.

Copper Pipe and Tubing

Copper pipe and tubing with soldered joints or flared-tube connectors are being used more for water service now than in the past. Copper is highly regarded because of its corrosion-resistant properties, flexibility, ease of installation, and low resistance to flow throughout its useful life.

Three types of copper, designated as Types K, L, and M, are commonly used. Type K is used for underground service and general plumbing; Type L for general plumbing; and Type M with soldered fittings only. Types K and L copper come in either straight 20-foot lengths of hard temper or in coils of 50 to 100 feet, soft temper. Type M comes in straight 20-foot lengths, hard drawn only.

Another type of copper, Type DWV (drain, waste, and vent), is used only in aboveground soil, waste, and vent lines. It is furnished in hard temper only and in sizes from 1 1/4 to 8 inches. It is available in 12-foot lengths as well as the standard 20-foot lengths.

The process used to soften copper is called "annealing." The word *anneal* means to soften thoroughly and render less brittle. Copper is unlike steel in many respects. If copper is bent often, it could break when you try to bend it again. Should the pressure on a copper tube increase or decrease too much, the tube could break. Vibration also makes copper tubing break.

To soften steel, heat it to a cherry red and cool it very slowly. The slower it is cooled, the softer the steel becomes. With copper, the opposite is true. Copper is heated uniformly to a dull red and then quenched (dipped) in water (for water service). The faster it is cooled, the softer the copper becomes.

BENDING COPPER.—Copper, properly annealed, can be bent by hand when sharp bends are not desired. Copper partially collapses during the bending process if a tubing bender is not used or if the copper is not filled with some kind of easily removable material, such as sand. Simple bends can also be made by wrapping the outside of the copper tightly with soft wire and bending the copper by hand. However, if a line must make a 45- or 90-degree bend, you should use a tubing bender. Hand-tubing benders are available for each size of copper. These benders assist you in making neat, accurate bends easily, quickly, and without marring the copper or restricting the flow through the copper. It is easy to make a bend, but difficult to get the bend in the correct location on the copper and to the correct degree. Be certain that you have the correct size bender for the copper you intend to bend. A bender that is either too small or too large for the copper will make a faulty bend. Figure 3-39 shows one type of tubing bender. Figure 3-40 shows a typical one-story copper DWV system.

MEASURING.—Seven methods are commonly used in measuring pipe, or tubing. They are (1) end to end, (2) center to center, (3) end to center, (4) end to back, (5) center to back, (6) back to back, and (7) face to face. These measurements are also commonly used in measuring threaded galvanized or black iron pipe.

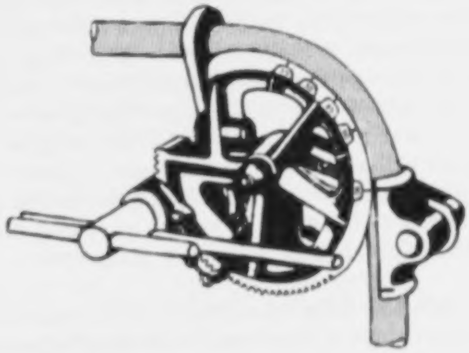


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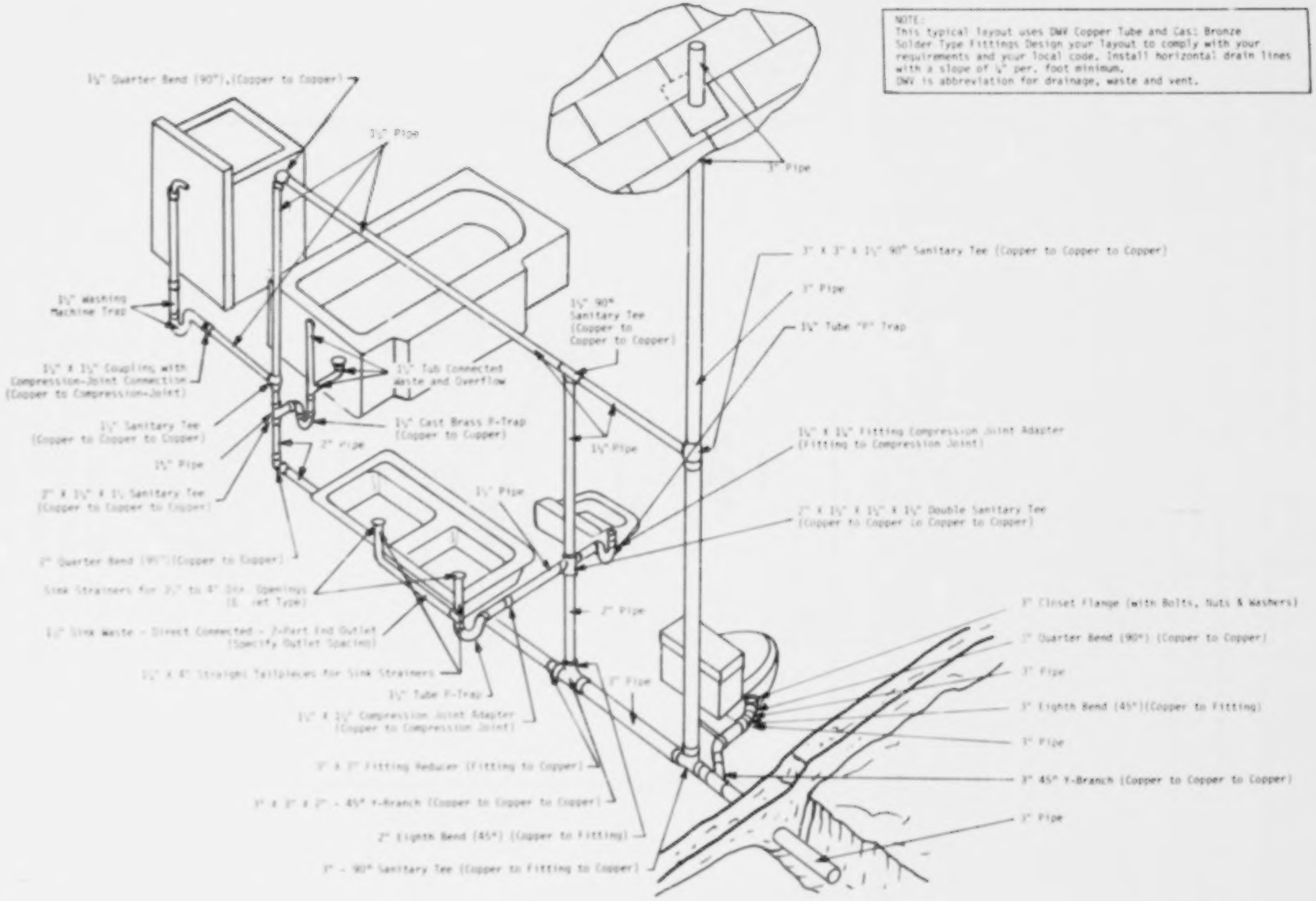
Figure 3-39.—Portable copper pipe and tubing bender.


1½" Quarter Bend (90°).(Copper to Copper)
1½" Pipe
1½" Washing Machine Trap
1½" X 1½" Coupling with Compression-Joint Connection (Copper to Compression-Joint)
1½" Sanitary Tee (Copper to Copper to Copper)
1½" Pipe
2" X 1½" X 1½ Sanitary Tee (Copper to Copper to Copper)
2" Quarter Bend (90°)(Copper to Copper)
Sink Strainers for 3½" to 4" Dia. Openings (E. ret Type)
1½" Sink Waste - Direct Connected - 2-Part End Outlet (Specify Outlet Spacing)
1½" X 4" Straight Tailpieces for Sink Strainers
1½" Tube P-Trap
1½" X 1½" Compression Joint Adapter (Copper to Compression Joint)
3" X 2" Fitting Reducer (Fitting to Copper)
3" X 3" X 2" - 45° Y-Branch (Copper to Copper to Copper)
2" Eighth Bend (45°) (Copper to Fitting)
3" - 90° Sanitary Tee (Copper to Fitting to Copper)
1½" Tub Connected Waste and Overflow
1½" Cast Brass P-Trap (Copper to Copper)
2" Pipe
1½" 90° Sanitary Tee (Copper to Copper to Copper)
1½" Pipe
1½" Pipe
2" Pipe
2" Pipe
3" Pipe
3" X 3" X 1½" 90° Sanitary Tee (Copper to Copper to Copper)
3" Pipe
1½" Tube "P" Trap
1½" X 1½" Fitting Compression Joint Adapter (Fitting to Compression Joint)
2" X 1½" X 1½" X 1½" Double Sanitary Tee (Copper to Copper to Copper to Copper)
3" Closet Flange (with Bolts, Nuts & Washers)
3" Quarter Bend (90°) (Copper to Copper)
3" Pipe
3" Eighth Bend (45°)(Copper to Fitting)
3" Pipe
3" 45° Y-Branch (Copper to Copper to Copper)
3" Pipe

NOTE:
This typical layout uses DWV Copper Tube and Cast Bronze Solder Type Fittings Design your layout to comply with your requirements and your local code. Install horizontal drain lines with a slope of ¼" per. foot minimum.
DWV is abbreviation for drainage, waste and vent.

54.464

Figure 3-40.—Typical one-story copper DWV system.

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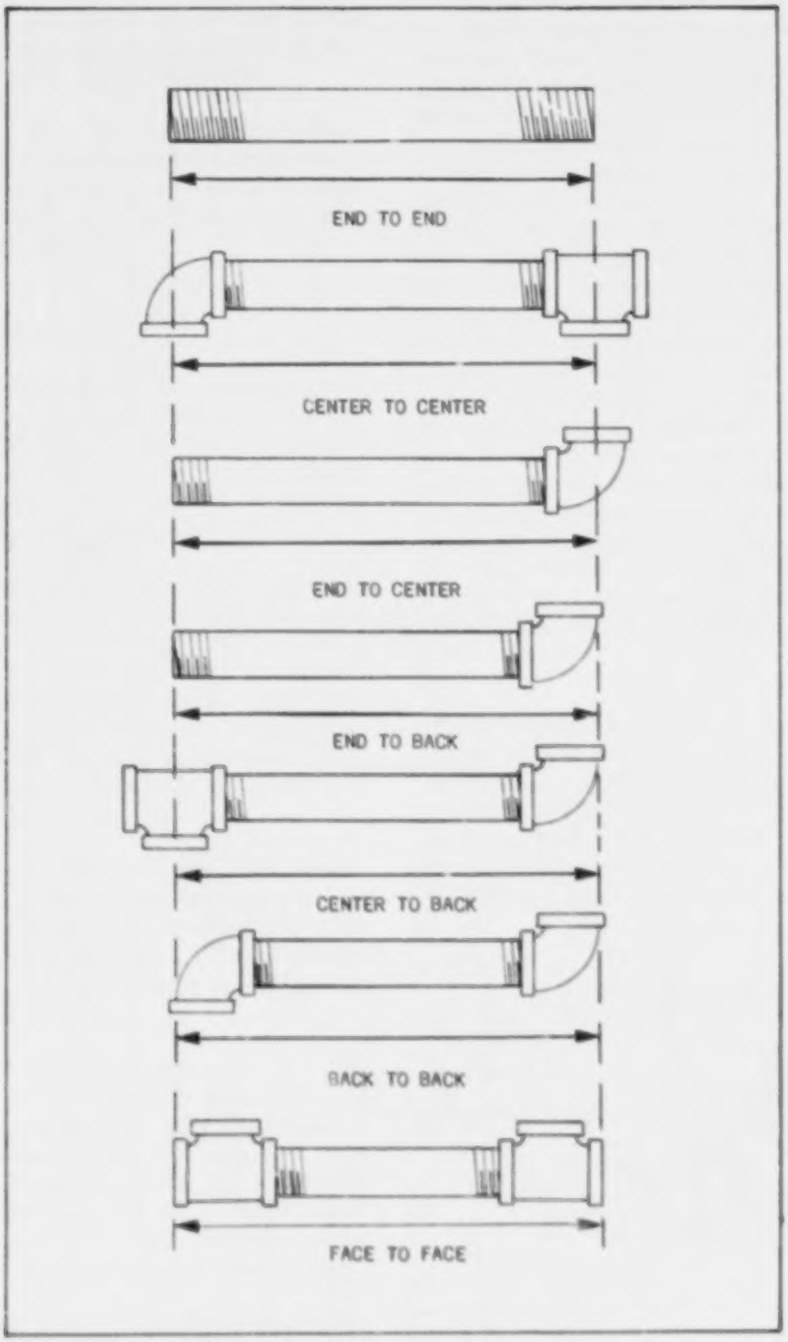

END TO END
CENTER TO CENTER
END TO CENTER
END TO BACK
CENTER TO BACK
BACK TO BACK
FACE TO FACE

54.465

Figure 3-41.—Methods of measuring pipe and tubing.

The measurements are generally made with a ruler. Each of the seven methods mentioned above is explained below, and each one is shown in figure 3-41.

END TO END indicates a pipe threaded on both ends. The measurement is from one end of the pipe to the other end, including both threads.

CENTER TO CENTER means there is a fitting on each end of the pipe. The measurement is made from the center of the fitting on one end to the center of the fitting on the other end.

END TO CENTER method applies to pipe having a fitting on one end. The measurement is made from the end of the pipe to the center of the fitting.

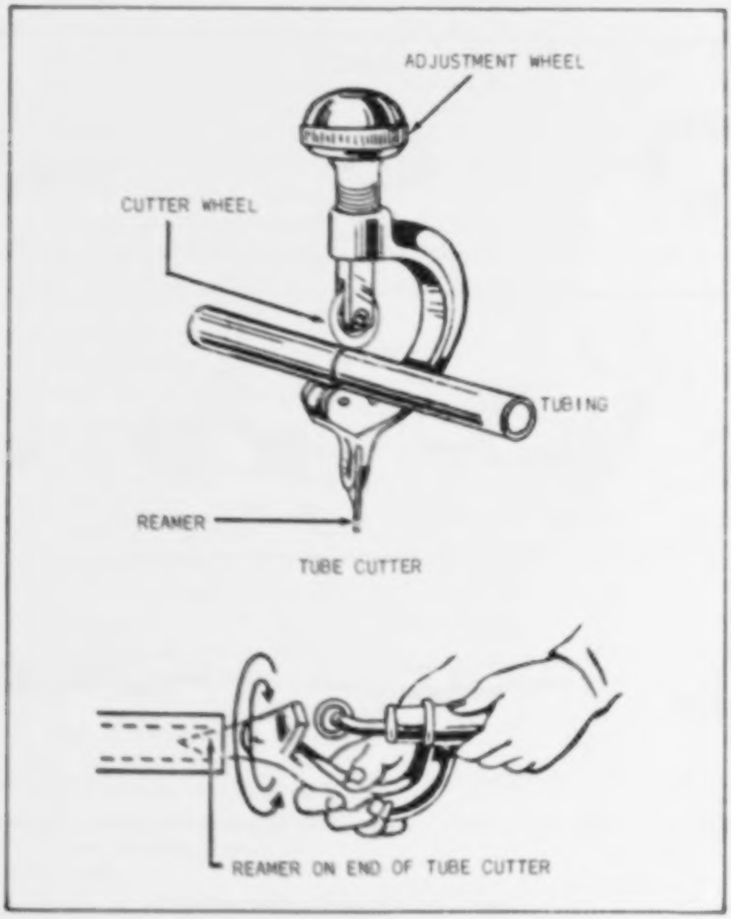
END TO BACK also refers to pipe with a fitting on one end. The measurement is from the back of the fitting to the other end of the pipe.

CENTER TO BACK indicates a pipe with a fitting on each end. The measurement is taken from the center of one fitting to the back of the other fitting.

BACK TO BACK measurement refers to pipe with a fitting on each end. Here the measurement is from the back of one fitting to the back of the other fitting.

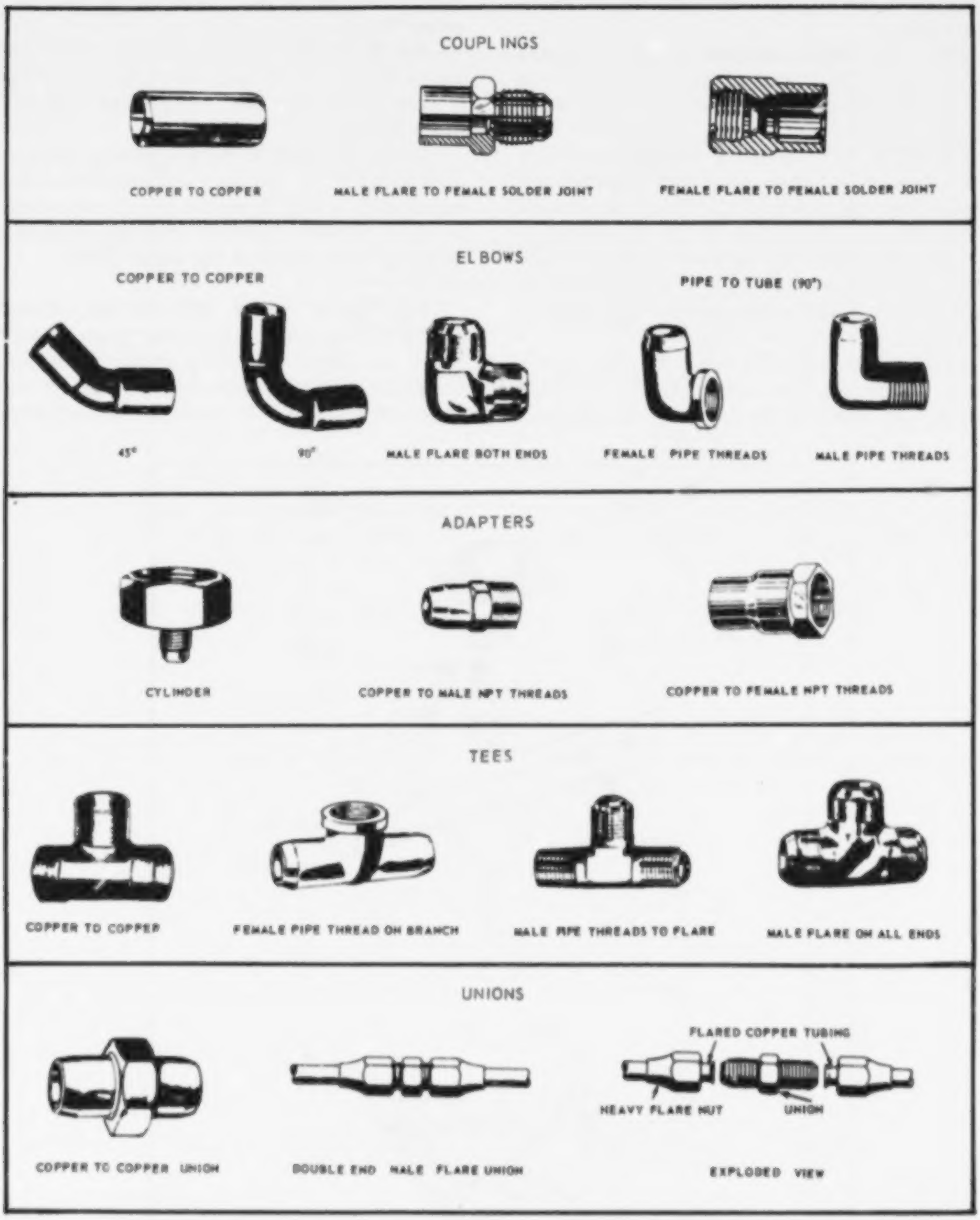
FACE TO FACE measurement refers to a pipe with a fitting on each end that has an opening directly across from the pipe it is connected to on both ends. Measure from the face of the opening to the face of the other fitting.

CUTTING AND REAMING.—Copper should be cut with a tube cutter when available. Mark the copper where it is to be cut and install the cutter so that the cutter wheel is over the mark, as shown in figure 3-42. Now turn the adjustment



44.164

Figure 3-42.—Cutting and reaming copper tubing.


COUPLINGS
COPPER TO COPPER
MALE FLARE TO FEMALE SOLDER JOINT
FEMALE FLARE TO FEMALE SOLDER JOINT
ELBOWS
COPPER TO COPPER
PIPE TO TUBE (90°)
45°
90°
MALE FLARE BOTH ENDS
FEMALE PIPE THREADS
MALE PIPE THREADS
ADAPTERS
CYLINDER
COPPER TO MALE NPT THREADS
COPPER TO FEMALE NPT THREADS
TEES
COPPER TO COPPER
FEMALE PIPE THREAD ON BRANCH
MALE PIPE THREADS TO FLARE
MALE FLARE ON ALL ENDS
UNIONS
FLARED COPPER TUBING
HEAVY FLARE NUT
UNION
COPPER TO COPPER UNION
DOUBLE END MALE FLARE UNION
EXPLODED VIEW

11.311A

Figure 3-43.—Typical copper fittings.

wheel or handle clockwise to force the cutter wheel against the copper. Continue revolving the cutter, turning the adjustment wheel slightly after each revolution until the copper is cut through and separates.

Copper may be cut with a hacksaw, although a tube cutter is preferable. However, be careful to cut the copper square if it is to be flared. Be sure to use a fine-toothed hacksaw blade, 32 teeth per inch, when cutting copper.

After cutting the copper, remove the burr inside the cut with the reamer on the tube cutter. Place the reamer in the end of the copper, and revolve the tube cutter clockwise until the burr is removed.

JOINING.—When working with copper, you use both flared and sweated joints. "Flaring" is a method of forming the end of the copper into a funnel shape, so it can be held in a threaded fitting when a line joint is being made. Before a flare is made, slip a flare nut on the copper. A common error is forgetting to put the nut on before making the flare. For additional information on making flared connections, refer to *Tools and Their Uses*, NAVEDTRA 10085-Bl. Figure 3-43 shows a few typical copper fittings.

A sweated joint is made with solder instead of threads, or flares. When making a soldered joint with a sweat fitting, clean an inch or more of the end of the copper tube with steel wool or 000 sandpaper until new metal appears. Clean the inside of the fitting in the same manner. Spread a thin film of paste flux on the tube end with a clean brush, or applicator. Do not apply paste with the finger, or an oily applicator.

Carefully insert the copper into the fitting to make them fit together very closely. Capillary action must spread the solder evenly and completely over the surfaces. However, the process is not effective with loose fits because of excess clearance. If the fit is loose, you may have to tin the end of the copper tube. "Tinning" is the process of applying a small amount of solder to the end of the copper before it is inserted into the sweat fitting.

In soft soldering, heat is applied directly to the metal with a flame. Various types of heat-generating equipment are available. In your work, however, you generally use methylacetylene propadiene (MAPP) cutting/welding equipment, or a Presto-lite heating unit.

The Presto-lite torch is ideal for SOFT SOLDERING, because it delivers a small controllable flame. The Presto-lite unit consists of a small MAPP-gas cylinder, regulator, rubber hose, torch, and two or more removable tips. This unit burns MAPP gas as a fuel in the presence of oxygen. Figure 3-44 gives you an idea of what the Presto-lite unit looks like.

When heating, apply heat to the fitting or thickest part until it reaches the melting temperature of the solder. Feed the solder at the edge of the fitting. When a continuous ring of solder appears at the end of the fitting, you have completed the joint.

After soldering is complete, clean the joints with a wire brush, soap and water, or emery cloth. Exercise caution to remove all flux from the joint after it is soldered. Any flux left on a joint causes corrosion.

In plumbing, you may occasionally be called upon to join copper pipe or tubing by silver brazing. You may also use silver brazing in making repairs to air-conditioning and refrigeration equipment, water systems, galley equipment, and so on.

In SILVER BRAZING, also called SILVER SOLDERING or HARD SOLDERING, joint members are fused by heating with a gas flame and silver alloy filler metal with a melting point above 800°F, but below the melting point of the

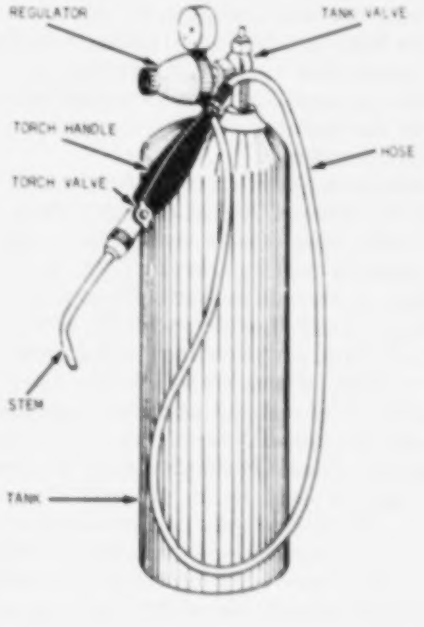


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Figure 3-44.—Presto-lite heating unit.

base metal. The filler metal is distributed in the joint by capillary attraction.

Since capillary attraction is important in the silver brazing process, it may help you to understand what this term means. Perhaps the best way to understand capillary attraction is to consider some everyday examples of the process. If you put one end of a strip of cloth in a glass of water and allow the other end to hang over the edge of the glass, the end of the cloth that is not in the water becomes wet. Water rises in the cloth by capillary attraction. When you use a blotter, the ink is drawn up into the blotter by capillary attraction. The wick on an oil lamp can be lit because the oil rises in the wick by capillary attraction. In each of these examples, we have a LIQUID (water, ink, oil) that moves into an opening in a SOLID (cloth, blotter, wick) by a process called "capillary attraction." A basic rule of capillary attraction is that the distance the liquid is drawn into the opening in the joint depends on the size of the opening in the joint—the smaller the opening, the farther the liquid is drawn in.

In just the same way, capillary attraction causes the melted filler metal used in silver brazing to be drawn into the narrow clearance between the joining members. Capillary attraction does not work unless the filler metal is melted and unless the size of the opening is quite small. Therefore, the application of heat and the use of a very small clearance between joining members are essential to silver brazing. The heat is necessary to melt the filler metal and to keep it molten; the small clearance is necessary to allow capillary attraction to draw the molten metal into the space between the joint members.

Silver-base alloys are commonly used as filler metal for brazing. Although filler metals other than silver-base alloys are often used, the technique for making a brazed joint is basically the same. A main difference is the amount of heat necessary to melt the filler metal. In all instances, this temperature is below the melting point of the base metals. Silver-brazed joints have high strength on ferrous and nonferrous metals. The strength of a properly made joint exceeds that of the metals joined. On stainless steel, it is possible to develop a joint tensile strength of approximately 130,000 pounds per square inch (psi). Since brazing with silver-based alloys is typical of brazing in general, it is especially interesting at this point to note the use of these materials as filler metal. This information applies equally to brazing with other filler metals that are distributed by capillary attraction.

There are two methods used to make joints between tubes and fittings in piping systems with silver-base brazing filler metal: the INSERT method and the FEED-IN method. With either method, the parts must be adequately supported during heating. The work must be held firmly in position until the brazing filler metal has completely solidified.

When using the insert method, insert a strip of the silver-base filler metal in the joint before assembly. Before brazing the parts, clean them with emery cloth, steel wool, or an acceptable cleaning solvent. Apply flux with a brush. Next, fit the two parts together and align them. Then light the torch and direct the heat on the tube or thinner portion, as shown in figure 3-45. The lines drawn on the tube indicate the path of the torch while heating the tube.

Heat applied to the tubing causes it to swell and bring the surface of the tube into contact with the inside surface of the fitting. This closes the clearance area, forcing the flux from either end of the joint. Be sure to heat the entire circumference of the tube until flux begins to flow. Flux flow tells you that the tube has expanded sufficiently. This is the signal to proceed to the second phase of heating. As soon as the flux flows freely, about 6 seconds after you see fluid, direct the flame to that portion of the fitting hub farthest from the junction of the tube and the fitting. Rotate the flame over the joint segment until brazing filler metal appears at the junction of the pipe and fitting. At that moment, flick the torch away so the flame wipes toward the pipe. This completes one segment of the joint. This procedure is repeated until all segments are completed. A satisfactory joint has a continuous

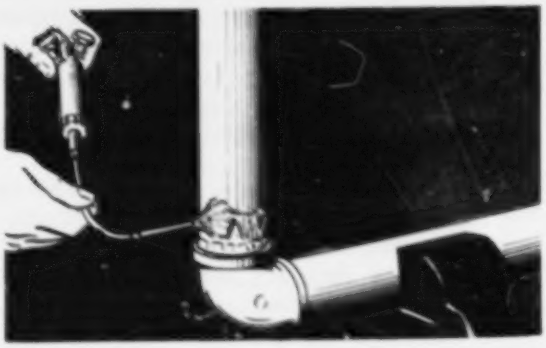

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Figure 3-45.—Applying heat for brazing a tube and fitting.

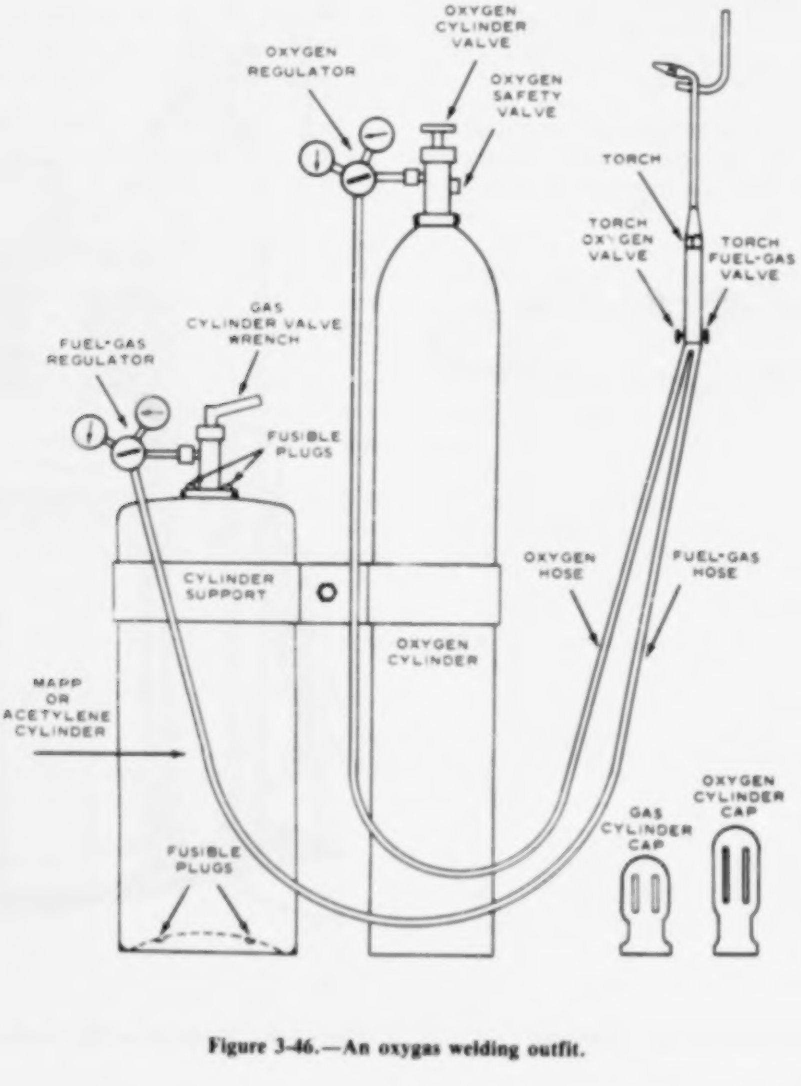
ring of filler metal at the end of the fitting. The ring must also be smooth and concave.

With the feed-in method, the parts are heated to the correct temperature. Watching the behavior of the flux is the best way to determine the temperature of the joint as the heating progresses. First, the flux dries out as the moisture (water) boils off. Then the flux turns milky and starts to bubble at about 600 °F. Finally, it turns into a clear liquid at about 1100 °F. This last temperature is just short of the brazing temperature. The clear appearance of the flux indicates the time to start adding the filler metal (silver solder). If the temperature and alignment are proper, the filler metal spreads over the metal surface and into the joint by capillary attraction. Make sure the filler metal penetrates the complete thickness of the metal for good bonding. Stop heating as soon as the filler metal has completely covered the surface of the joint. Then, allow the joint to cool before moving so the filler metal solidifies.

Gas-welding Equipment

A number of different types of equipment are used in silver brazing. In your work, silver brazing can probably be accomplished by the use of methylacetylene propadiene (MAPP) cutting/welding equipment.

A commonly used oxygas welding outfit (fig. 3-46) consists of a cylinder of acetylene or


OXYGEN CYLINDER VALVE
OXYGEN REGULATOR
OXYGEN SAFETY VALVE
TORCH
TORCH OXYGEN VALVE
TORCH FUEL-GAS VALVE
GAS CYLINDER VALVE WRENCH
FUEL-GAS REGULATOR
FUSIBLE PLUGS
CYLINDER SUPPORT
OXYGEN HOSE
FUEL-GAS HOSE
OXYGEN CYLINDER
MAPP OR ACETYLENE CYLINDER
OXYGEN CYLINDER CAP
GAS CYLINDER CAP
FUSIBLE PLUGS

127.367

Figure 3-46.—An oxygas welding outfit.

MAPP gas or a cylinder of oxygen, two regulators, two lengths of hose with fittings, and a welding handle with tips. An oxygas outfit also is called a "welding rig."

In addition to the basic equipment mentioned above, numerous types of auxiliary equipment are used in oxygas welding. A very important item is the spark igniter that is used to light the torch (view A, fig. 3-47). Another item you will use a lot is an apparatus wrench, the same or similar in design to that shown in view B, figure 3-47. The apparatus wrench is sometimes called a "gang wrench" because it fits all the connections on the welding rig. Note that the wrench shown has a raised opening in the handle that serves as an acetylene tank key. Other common accessories include tip cleaners, cylinder tracks, clamps, and holding jigs. Safety apparel, such as goggles, handshields, gloves, leather aprons, sleeves and leggings, also is essential and should be worn as required for the job at hand.

Oxygas welding equipment may be stationary or portable. A portable oxygas outfit, such as that shown in figure 3-48, is advantageous where the equipment must be moved around from one job to another.

To carry out your welding duties, you must be able to set up the welding equipment and make various adjustments required to perform the operation at hand. Thus, you should understand the purpose and function of the basic pieces of equipment that make up the welding outfit. Before discussing the apparatus, look at the gases used in gas welding, particularly MAPP gas and oxygen.

MAPP GAS.—MAPP gas is an all-purpose industrial fuel that has the high-flame temperature

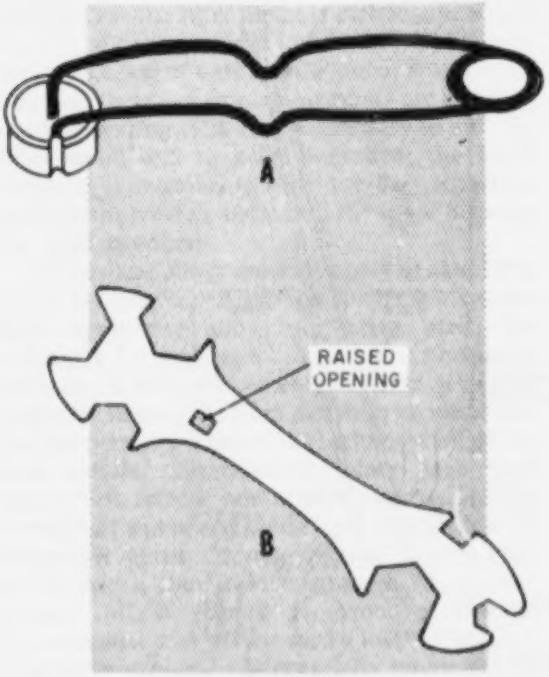


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Figure 3-47.—Auxiliary equipment.

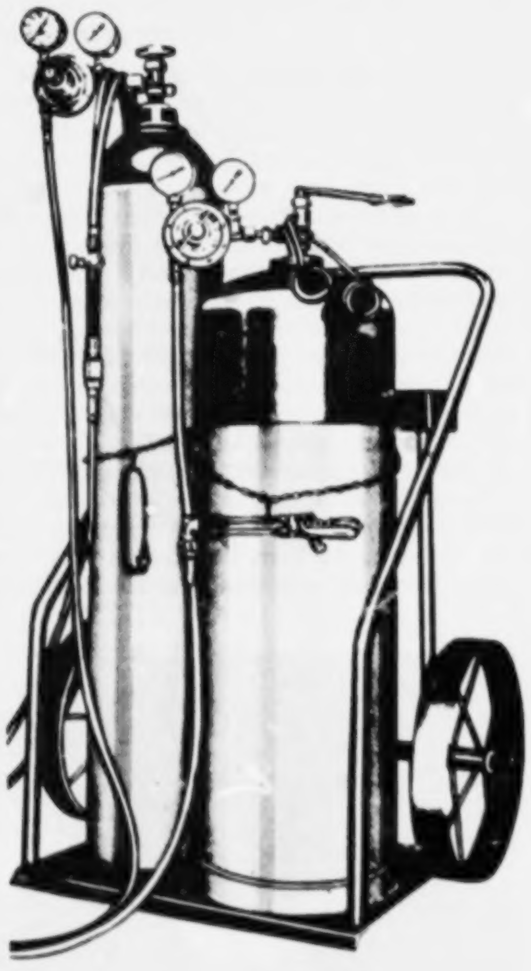

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Figure 3-48.—A portable oxygas welding and cutting outfit.

of acetylene and the handling characteristics of propane.

Being a liquid, MAPP is obtained by the pound rather than by the cubic foot, as with acetylene. One 70-pound cylinder of MAPP gas does the work of more than six and one-half 225-cubic-foot-acetylene cylinders. This is a ratio of 70 pounds of MAPP gas to about 1,450 cubic feet of acetylene.

Total weight for the 70-pound MAPP cylinder, which is the same physical size of a 225-cubic-foot-acetylene cylinder, is 120 pounds when full.

MAPP cylinders contain only liquid fuel. There is no cylinder packing of acetone to impair fuel withdrawal. For heavy-use situations, a MAPP cylinder delivers more than twice as much gas as an acetylene cylinder for longer periods of time. The entire contents of a MAPP cylinder can be used, since there is no acetone that could be drawn into the regulators or the torch. As the gas burns with oxygen, it produces a flame temperature of 5300°F (2927°C) and equals or exceeds the performance of acetylene for cutting, heating, and brazing because of its superior heat transfer characteristics.

Acetylene regulators, hoses, torches, and welding tips may be used without any significant disparity. Very often the same-size tip can be used for welding with MAPP gas as with acetylene. However, it is recommended that a tip one or two sizes larger be used with MAPP gas for optimum results. Table 3-2 is a good guide to follow when you are using acetylene tips for MAPP-gas welding.

MAPP is not sensitive to shock, and it is nonflammable in the absence of oxygen. There is no chance of an explosion if a cylinder is bumped, jarred, or dropped. The cylinders can be stored for transporting in any position without danger of an explosive air pocket being formed. The characteristic odor, while harmless, gives warnings of fuel leaks in the equipment long before danger.

MAPP gas is not restricted to a maximum working pressure of 15 psig as is acetylene. In jobs requiring higher pressures and gas flows, MAPP at the full-cylinder pressure of 95 psig at 70°F (21°C) can be used safely.

Welding and brazing with MAPP gas require some differences in equipment and technique.

Prepare steel to be welded with MAPP the same as for welding with acetylene. For metals thinner than one eighth of an inch (3.1 mm), clean the metal to be welded well, either with a wire brush or a grinding wheel. When metal is thicker than one eighth of an inch, bevel it first and clean it thoroughly.

Position the steel with a root opening equal to the material thickness when the work is thinner than one eighth of an inch. If the metal is thicker than one eighth of an inch, leave a gap equal to the diameter of the welding rod to be used.

Set the gauge pressure with the torch valves closed; if the metal to be welded is three sixteenth of an inch (4.2 mm) or less, set the gas (MAPP) pressure at 2-3 psig and the oxygen pressure at 10-15 psig. When working with one fourth of an inch (6.2 mm) or thicker steel, set MAPP-gas pressure at 4-5 psig and oxygen pressure at 15-20 psig.

When indoors or in an enclosed area, you should light the torch by slightly cracking the gas valve on the torch. Light it with an approved friction lighter and then open the oxygen valve

Table 3-2.—Substituting Acetylene Tips for MAPP Gas Use

DRILL SIZE OF TIP	INNER FLAME LENGTH, IN.	REGULATOR PRESSURE RANGE		MAPP GAS CONSUMPTION CFH	METAL THICKNESS, INCHES
		MAPP GAS	OXYGEN		
72-70	1/4	1-2	5-6	1-3	UP TO 1/32
65-60	7/16	1-3	5-6	2-4	1/32-1/16
59-54	5/8	1/5	6-8	3-8	1/16-1/8
49-48	1	2-8	8-10	5-18	1/8 -3/16
43-40	1 1/8	3-9	10-12	6-30	3/16-1/4
36	1 1/4	5-10	12-15	6-35	1/4 -3/8

to obtain a neutral flame (very blue), which is best for welding. Outdoors, or when working where there is a draft, or when a smokeless flame is desired, crack the oxygen and gas valves slightly, light the torch, and adjust it to a neutral flame.

Check the cone length and make sure the flame is neutral. (See fig. 3-49.) **REMEMBER THAT THE NEUTRAL MAPP-GAS FLAME IS LONGER THAN THAT OF THE ACETYLENE FLAME.**

Flame adjustment is the most important step of successful welding with MAPP gas. As with all other fuel gases, there are three basic types of gas flames: carburizing, neutral, and oxidizing. (See fig. 3-49.)

A carburizing flame looks much the same with MAPP as with acetylene. It has a yellow feather on the end of the primary cone. Slightly carburizing or reducing flames are used when you are welding easily oxidized alloys, such as aluminum.

As the oxygen is increased or the fuel gas decreased, the carburizing feather pulls off and disappears, and the inner flame becomes a deep blue. This neutral flame (fig. 3-49) is ideal for welding. Increasing the oxygen flow produces a lighter blue flame, a longer inner cone, and a louder burning sound to give you an oxidizing MAPP-gas flame.

Occasionally a harsh, bushy flame may be required for a job; in such cases, counterboring is needed to give a harsh, yet stable, flame with MAPP gas. Table 3-3 lists the counterbore drill for use with each acetylene tip drill size. In every case, the depth of the counterbore is one sixteenth of an inch.

Bulk MAPP-gas facilities, similar to liquid oxygen stations, are installed at some activities where large supplies of gas are used. In a bulk installation, MAPP gas is delivered through a piping system direct to the points where it is used. Maximum pressure is controlled centrally for efficiency and economy.

Cylinder filling facilities are also available from bulk installations that allow users to fill their cylinders on site. Filling a 70-pound MAPP cylinder takes one person approximately 1 minute and is essentially like pumping water from a large tank to a smaller one.

MAPP-GAS SAFETY.—Liquified MAPP gas is insensitive to shock. A MAPP-gas cylinder does not detonate when dented, dropped, hammered, or even incinerated. It may also be safely used up to full-cylinder pressures. The gas vapors up to 419°F and 285 psig do not decompose when subjected to an energy source in the absence of oxygen. The vapor is also stable up to 600°F and 1,100 psig when exposed to an 825°F probe. The explosive limits of MAPP gas are 3.4 percent to 10.8 percent in air, or 1.5 percent to 60 percent in oxygen. These limits are very narrow in comparison with acetylene. (See fig. 3-50.)

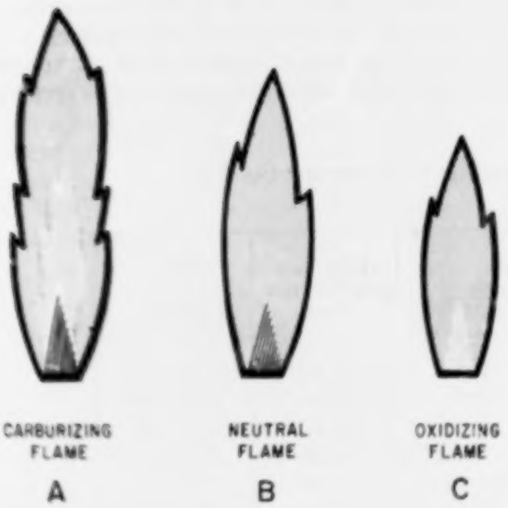

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Figure 3-49.—MAPP-gas flames.

Table 3-3.—Counterboring Welding Tips for MAPP Gas

Tip Drill Size	Counterbore Drill	Tip Drill Size	Counterbore Drill
76	52	52	36
74	51	50	34
72	50	48	33
70	49	46	32
68	48	44	31
66	47	42	30
64	46	40	29
62	45	38	28
60	44	36	27
58	43	34	26
56	42	32	25
54	39	30	24

NOTE: All counterboring is to 1/16 in. depth.

MAPP gas has a detectable odor at 100 ppm, or at a concentration 1/340 of its lower explosive limit.

Small fuel-gas systems may leak 1 or 1 1/2 pounds of fuel or more in an 8-hour shift; bulk systems leak even more. Fuel-gas leaks are often difficult to find, and often times go unnoticed. However, a MAPP-gas leak is easy to detect and can be repaired before it becomes dangerous.

MAPP toxicity is rated very slight, but high concentrations (5,000 ppm) may have an anesthetic effect. Local eye or skin contact with MAPP-gas vapor causes no adverse effect. The **LIQUID FUEL MAY CAUSE DANGEROUS FROSTLIKE BURNS** because of the temperature at which MAPP gas must be stored.

OXYGEN.—Oxygen is a colorless, tasteless, and odorless gas slightly heavier than air. It is not flammable but supports combustion with other elements. In its free state, oxygen is one of the most common elements. The atmosphere is made up of approximately 21 parts of oxygen and 78 parts of nitrogen, the remainder being rare gases. Rusting of ferrous (containing iron) metals, discoloration of copper, and the corrosion of aluminum are all due to the action of atmospheric oxygen. This action is called "oxidation."

Oxygen is obtained commercially either by the liquid-air process or by the electrolytic process. In the liquid-air process, the air is compressed and then cooled to a point where the gases become liquid (approximately −375 °F or −225 °C). The temperature is then raised to above −321 °F (−196 °C), at which point the nitrogen in the air becomes gas again and is removed. When the temperature of the remaining liquid is raised to −297 °F (−183 °C), the oxygen forms gas and is taken off. The oxygen is then further purified and compressed into cylinders for use.

The electrolytic process, the other process by which oxygen is obtained, consists of running an electric current through water to which an acid or alkali has been added. The oxygen collects at the positive terminal and is passed off through pipes to a container.

When supplied for use in oxyacetylene welding, oxygen is contained in seamless steel cylinders. A typical oxygen cylinder is shown in figure 3-51. Oxygen cylinders are made in several sizes. However, you will probably find the size

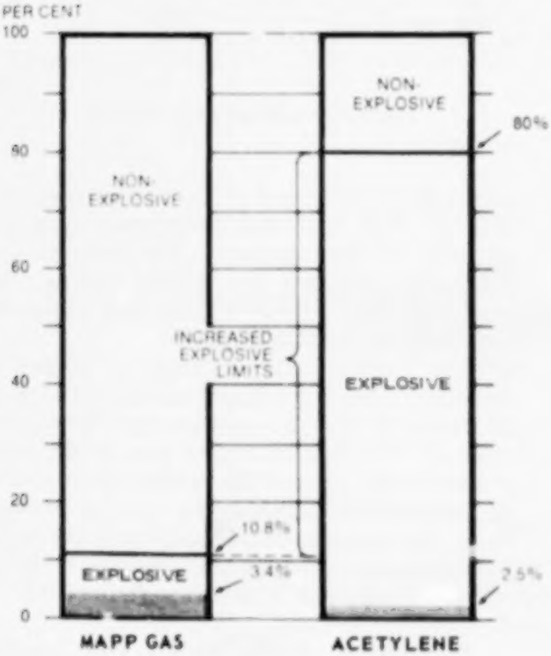

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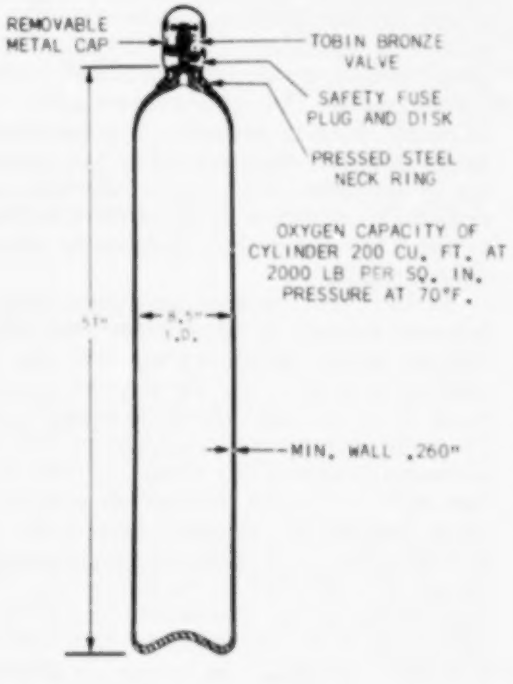
Figure 3-50.—Explosive limits of MAPP gas and acetylene in air.


REMOVABLE METAL CAP
TOBIN BRONZE VALVE
SAFETY FUSE PLUG AND DISK
PRESSED STEEL NECK RING
OXYGEN CAPACITY OF CYLINDER 200 CU. FT. AT 2000 LB PER SQ. IN. PRESSURE AT 70°F.
51"
8.5"
I.D.
MIN. WALL .260"

127.16

Figure 3-51.—Typical oxygen cylinder.

most generally used in welding and cutting is the 200-cubic-foot-capacity cylinder. It is 9 1/8 inches in diameter and weighs about 145 pounds. This cylinder is charged to a pressure of 2,000 psi at a room temperature of 63°F (17.2°C).

You can tell the amount of oxygen in a compressed-gas cylinder by reading the volume scale on the high-pressure gauge attached to the regulator.

REGULATORS.—The gas pressure in a cylinder must be reduced to a suitable working pressure before it can be used. This pressure is reduced by a regulator, or reducing valve. Regulators that control the flow of gas from the cylinder are either single stage or double stage. Single-stage regulators reduce the pressure of the gas in one step, while two-stage regulators perform the same work in two steps or stages. Generally, less adjustment is necessary when two-stage regulators are used.

Figure 3-52 shows two SINGLE-STAGE regulators: one for acetylene and one for oxygen. The regulator mechanism consists of a nozzle through which the high-pressure gases pass, a valve seat to close off the nozzle, a diaphragm, and balancing springs. These items are all enclosed in a suitable housing. Pressure gauges indicate the pressure in the cylinder or pipeline (inlet), as well as the working pressure (outlet). The inlet pressure gauge, used to record cylinder pressures, is a high-pressure gauge. The outlet pressure gauge, used to record working pressures, is a low-pressure gauge. Acetylene regulators and oxygen regulators are of the same general type, although those designed for acetylene are not made to withstand as high a pressure as those designed for use with oxygen cylinders.

In the oxygen regulator, the oxygen enters the regulator through the high-pressure inlet connection and passes through a glass wool filter that removes dust and dirt. Turning the adjusting screw IN (to the right) allows the oxygen to pass from the high-pressure chamber to the low-pressure chamber of the regulator, through the regulator outlet, and through the hose to the torch. Turning the adjusting screw to the right INCREASES the working pressure; turning it to the left DECREASES the working pressure. The high-pressure gauge is graduated in pounds per square inch from 0 to 3,000 and in cubic feet from 0 to 220. The gauge can be read to determine cylinder pressure and cubic content. Gauges are graduated to read correctly at 70°F (21°C). The working-pressure gauge is graduated in pounds per square inch from 0 to 150 or less, from 0 to 200, or from 0 to 400, depending upon the purpose of the regulator. For example, on regulators designed for heavy cutting, the working-pressure gauge is graduated in pounds per square inch from 0 to 400.

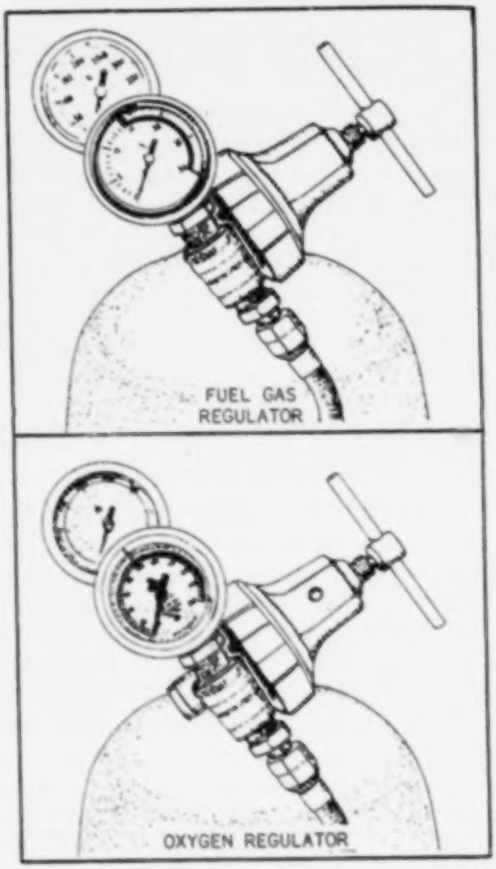


Figure 3-52.—Single-stage regulator.

The TWO-STAGE regulator is similar in principle to the single-stage regulator. The main difference is that the total pressure drop takes place in two steps instead of one. In the high-pressure stage, the cylinder pressure is reduced to an intermediate pressure. In the low-pressure stage, the pressure is reduced from the intermediate pressure to a working pressure. A typical two-stage regulator is shown in figure 3-53.

WELDING TORCHES.—The oxygas welding torch mixes oxygen and MAPP gas in the proper proportion and controls the amount of the mixture at the welding tip. Torches have two needle valves: one for adjusting the flow of oxygen and the other for adjusting the flow of MAPP gas. Other basic parts include a handle, two tubes (one for oxygen and another for MAPP gas), a mixing head, and a tip. On some models, the tubes are silver brazed to the head and the rear end forgings, which, in turn, are fitted into the handle. Welding tips are made from copper and are available in different sizes to handle a wide range of plate thicknesses.

There are two general types of welding torches: a low-pressure type and a medium-pressure type. In the low-pressure torch, also known as an injector-type torch, MAPP-gas pressure per square inch is kept at about 1 pound. The oxygen pressure ranges from about 10 to 40 pounds according to the size of the torch tip. A jet of relatively high-pressure oxygen produces the suction necessary to draw the MAPP gas into the mixing head. The welding tips may have separate injectors in the tip. A typical mixing head for the low-pressure (or injector-type) torch is shown in figure 3-54.

Medium-pressure torches are sometimes called balanced-pressure or equal-pressure types, since

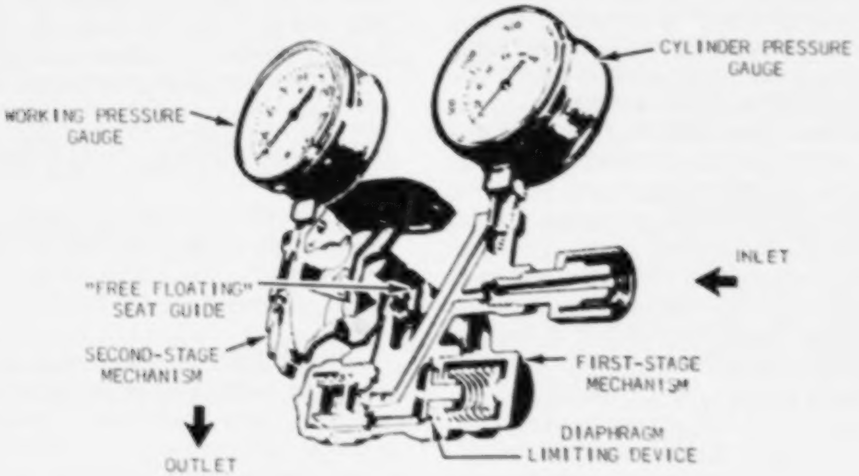

CYLINDER PRESSURE GAUGE
WORKING PRESSURE GAUGE
INLET
"FREE FLOATING" SEAT GUIDE
SECOND-STAGE MECHANISM
FIRST-STAGE MECHANISM
OUTLET
DIAPHRAGM LIMITING DEVICE

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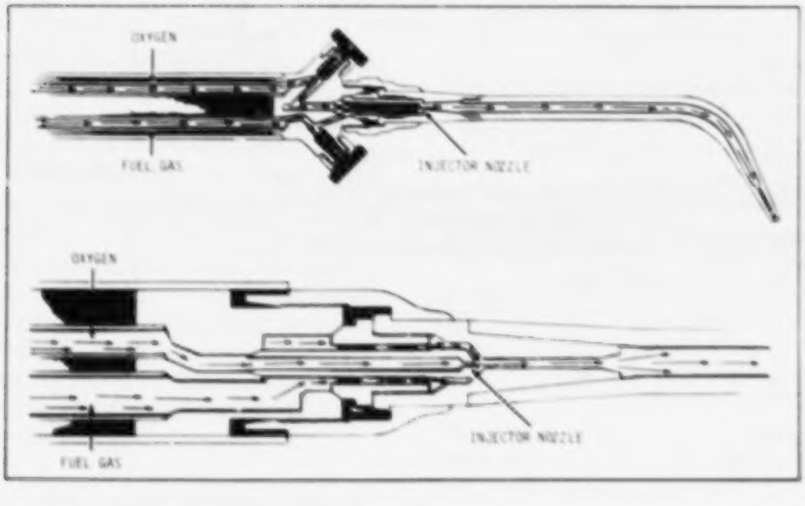
Figure 3-53.—Two-stage regulator.


OXYGEN
FUEL GAS
INJECTOR NOZZLE
OXYGEN
INJECTOR NOZZLE
FUEL GAS

11.101

Figure 3-54.—Mixing head for low-pressure torch.

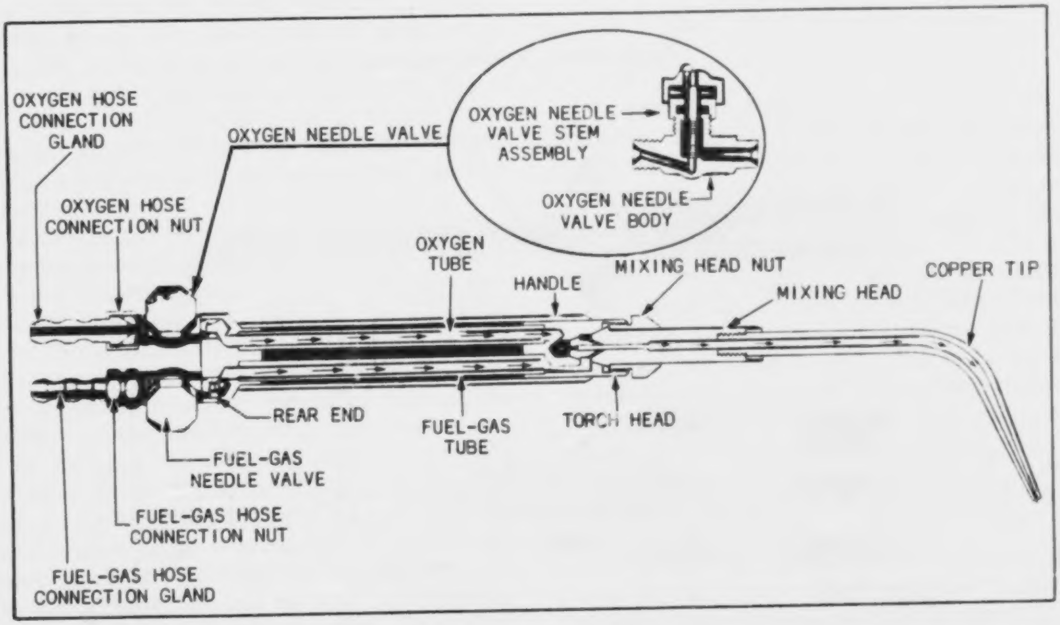
the acetylene and the oxygen pressure are kept equal. Pressure per square inch may be from 1 to 6 or 8 pounds; acetylene pressure must never be allowed to exceed 15 psi. A typical equal-pressure general-purpose torch is illustrated in figure 3-55. The medium-pressure torch is easier to adjust than the low-pressure torch and, since equal gas pressures are used for the medium-pressure torch, you are less likely to get a flashback; the flame is less likely to catch in or behind the mixing chamber. More details on flashback are given later in this chapter.

Welding TIPS and MIXERS are designed in several ways, depending on the manufacturer. Some makes of torches have a separate mixing head or mixer for each size of tip. Other makes have only one mixer for several tip sizes. Tips come in various types. Some are the one-piece, hard copper tips. Others are two-piece tips and include an extension tube to make connection between the tip and the mixing head. When the removable tips are used with an extension tube, they are made of hard copper, brass, or bronze. Tip sizes are designated by numbers, and each manufacturer has an arrangement for classifying them. Tip sizes differ in the diameter of the hole to obtain the correct volume of heat for the work to be done.

HOSE.—Hose used to make the connection between a torch and a regulator is strong, nonporous, and sufficiently flexible and light to make torch movements easy. It is made to withstand high-internal pressures. The rubber used in its manufacture is specially treated to remove sulfur to avoid the danger of spontaneous combustion. Welding hose comes in various sizes, depending upon the size of work for which it is intended. Hose used for light work is 3/16- or 1/4-inch-inside diameter, and it has one or two plies of fabric. For heavy-duty welding and cutting operations, hose with a 5/16-inch-inside diameter and three to five plies of fabric should be used. Single hose comes in lengths of 12 1/2 feet to 25 feet. Some manufacturers make a double hose that conforms to the same general specifications. The hoses used for acetylene and oxygen are the same in grade, but they differ in color. Oxygen hose is GREEN; MAPP-gas hose is RED.

CAUTION: Use NO oil, grease, or any other lubricant on welding (or cutting) apparatus. Oil or grease in the presence of oxygen under pressure ignites violently!

FILLER RODS.—The term *filler rod* refers to a filler metal, in wire or rod form, for use in


OXYGEN HOSE CONNECTION GLAND
OXYGEN NEEDLE VALVE
OXYGEN NEEDLE VALVE STEM ASSEMBLY
OXYGEN NEEDLE VALVE BODY
OXYGEN HOSE CONNECTION NUT
OXYGEN TUBE
HANDLE
MIXING HEAD NUT
MIXING HEAD
COPPER TIP
REAR END
FUEL-GAS TUBE
TORCH HEAD
FUEL-GAS NEEDLE VALVE
FUEL-GAS HOSE CONNECTION NUT
FUEL-GAS HOSE CONNECTION GLAND

11.102

Figure 3-55.—Equal-pressure welding torch.

gas welding and brazing processes and certain electric welding processes in which the filler metal is not a part of the electric circuit. A filler rod serves only one purpose; it supplies filler metal to the joint.

Filler rods for steel are often coated with copper to protect them from corrosion during storage. Most rods are furnished in 36-inch lengths and a wide variety of diameters, ranging from 1/32 to 3/8 inch. Rods for welding cast iron vary from 12 to 24 inches in length and are frequently square rather than round in cross section. The rod diameter selected for a given job is governed by the thickness of the metals being joined. Except for the rod diameter, the filler rod selected is determined by military (MIL) specification on the basis of the metals being joined.

Many different types of rods are manufactured for welding ferrous and nonferrous metals. In general, welding shops stock only a few basic types suitable in all welding positions. These basic types are known as general-purpose rods.

SELECTION OF WELDING TORCH TIP SIZE.—Welding torch tip size is designated by a number stamped on the tip. The tip size is determined by the size of the orifice. There is no standard system of numbering welding torch tip sizes; each manufacturer has a numbering system. In this manual, tip size instructions are given in orifice "Numbers drill" size. Number drills consist of a series of 80 drills, Numbers 1 through 80. Once you know a manufacturer's torches and numbering system, you rarely have to refer to orifice number drill sizes.

Since the orifice size determines the amount of acetylene and oxygen fed to the flame, the orifice determines the amount of heat produced by the torch. The larger the orifice, the greater the amount of heat generated. For practice purposes with a balanced, pressure-type torch, use table 3-4.

If the torch tip orifice is too small, not enough heat is available to bring the metal to its melting and flowing temperature. If the torch tip is too large, poor welds result because the weld has to be made too fast, the welding rod melting is hard to control, and the appearance and quality of the weld are unsatisfactory.

SECURING OXYGAS WELDING EQUIPMENT.—To extinguish the oxygas flame and to secure equipment after completing a job, or to interrupt work temporarily, take the following steps:

1. Close the MAPP-gas needle valve first, then close the oxygen needle valve to extinguish the flame.
2. Close both the oxygen and the MAPP-gas cylinder valves. Leave the oxygen and MAPP-gas regulators open temporarily.
3. Open the MAPP-gas needle valve on the torch and allow gas in the hose to escape (5-15 seconds) to the outside atmosphere. Do not allow gas to escape into a small or closed compartment. Close the MAPP-gas needle valve.
4. Open the oxygen valve on the torch and allow gas in the hose to escape (5-15 seconds). Close the valve.
5. Close both oxygen and MAPP-gas cylinder regulators by backing out the adjusting screws until they are loose.

Follow the above procedure whenever your work is interrupted for an indefinite period. When work is to stop for only a few minutes, you do not have to secure the cylinder valves nor drain the hose. However, for any indefinite work stoppage follow the entire extinguishing and securing procedure. For overnight work stoppage in areas other than the shop, it is safer to remove the pressure regulators and the torch from the system. Double-check the cylinder valves to make sure they are closed securely.

Maintenance of Equipment

Welding equipment must be kept up if it is to work well for a long time. You do not have to

Table 3-4.—Welding Rod Sizes and Tip Sizes Used to Weld Various Thicknesses of Metal

Metal Thickness	Diameter Welding Rod *	Tip Drill Size
1/16	1/16-3/32	60-69
1/8	3/32-1/8	54-57
1/4	5/32-3/16	44-52
3/8	3/16-1/4	40-50

*Sizes listed in this table are approximate and will give satisfactory results. The size of the piece welded will govern the choice. When welding small pieces use the smaller tip and welding rod. When welding larger pieces use the larger size tip and welding rod.

make repairs to welding equipment; but when repairs are needed, see that the equipment is removed from service and turned in for repair. You are responsible for various duties in the maintenance and care of oxygas welding equipment. This section identifies some of the common types of maintenance duties that you can expect to perform.

Ensure welding torches are kept away from oil and grease. At times, the needle valve may fail to shut off when hand-tightened in the usual manner. If so, do not use a wrench to tighten the seat in the valve stem. When foreign matter cannot be blown off the seat, remove the stem assembly and wipe the seat clean before reassembling. Be sure and keep the mixer seat free of dust, dirt, and other foreign matter.

Before a new torch is used for the first time, check the packing nut on the valves to make sure it is tight. Some manufacturers ship torches with these nuts loose.

Welding tips get rough treatment at times. So keep the orifice smooth and clean if you want the tip to work well. When cleaning a welding tip, do not enlarge or scar it. Remove carbon deposits and slag regularly.

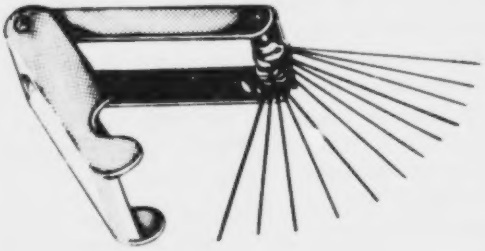
Avoid dropping a tip because the seat that seals the joint may be damaged. The flame end of the tip may receive mechanical damage if you let it contact the welding work, the bench, or the firebricks. This damage can roughen the end of the tip and cause the flame to burn with a "fishtail."

Special welding tip cleaners, as shown in view A, figure 3-56, have been developed to perform this service satisfactorily. The cleaner consists of a series of broachlike wires which correspond in diameter to the diameter of the tip orifices. These wires are packaged in a holder that makes their use safe and convenient. View B, figure 3-56, shows a tip cleaner in use. Some welders prefer to use a number drill that is the size of the tip orifice to clean welding tip orifices. A number drill must be used carefully so that the orifice is not enlarged, bell-mouthed, reamed out of round, or otherwise deformed.

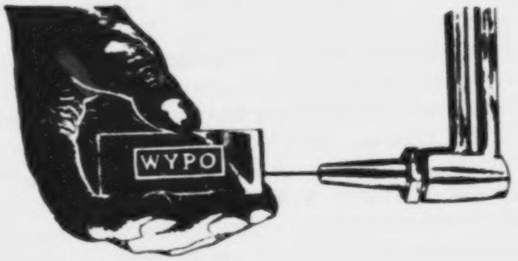
The flame end of the tip must be clean and smooth. Its surface must be at right angles to the center line of the tip orifice for a correctly shaped flame. A 4-inch mill file is commonly used to recondition this surface, as shown in view C, figure 3-56.

Should the end of the torch tip become rough and pitted and the orifice become bell-mouthed, recondition the tip. Place a piece of emery cloth, grit side up, on a flat surface; hold the tip perpendicular to the emery cloth; then, rub it back and forth just enough to true the surface and to bring the orifice back to its original diameter.

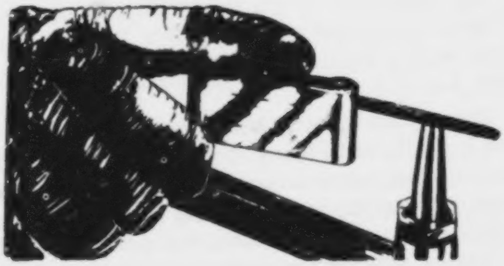
If there is leakage around the TORCH VALVE STEM, tighten the packing nut, and repack if necessary. For repacking, make sure you use only packing recommended by the



A. WELDING TIP ORIFICE CLEANER



B. A WELDING TIP CLEANER IN USE



C. RECONDITIONING THE ORIFICE END OF A TORCH TIP

127.373

Figure 3-56.—Reconditioning the orifice end of a torch tip.

manufacturer of the torch. **DO NOT USE ANY OIL.** If the valve stem happens to be bent or badly worn, replace it with a new stem.

A symptom of LEAKY VALVES is a continuous flow of gases after the valves are closed. Leaky valves are often caused by a dirty or damaged seat. To clean the seat, remove the valve assembly and wipe the seating portions of both valve stem and valve body with a clean rag. If the leak continues, try closing the valve tightly several times. When these measures fail to stop the leak, you may have to replace parts, or the valve body may have to be reseated. These repairs should be made only by qualified personnel.

Leaks in the MIXING-HEAD SEAT of the torch cause oxygen and MAPP-gas leaks between the inlet orifices leading to the mixing head. This defect can cause improper mixing of the gases and result in flashbacks. This defect can be corrected by reaming out the seat in the torch head and by truing the mixing-head seat. You may have to send the equipment to the manufacturer for these repairs, since special reamers are required for truing seats.

With regulators, gas leakage between the REGULATOR SEAT and NOZZLE is a common type of trouble. This defect can be detected by a gradual rise in pressure on the working-pressure gauge when the adjusting screw is fully released or is in position after adjustment. Frequently, this trouble, known as CREEPING REGULATOR, is caused by worn or cracked seats. It can also be brought on by foreign matter lodged between the seat and the nozzle. Regulators with leaks across the seats must be repaired at once; otherwise, damage to other parts of the regulator or apparatus can result. Leaks are particularly dangerous in acetylene regulators because acetylene, at a very high pressure in the hose, becomes an explosive hazard. To ensure the safety of personnel and equipment, see that regulators with such leaks are removed from service and turned in for repair.

Another important aspect of welding safety is protecting your eyes and the vision of helpers, chippers, or inspectors where someone is soldering or silver brazing. Ensure you are aware of hazards, such as stray flashes, reflected glare, flying sparks, and bits of molten metal. Look at the eye cover in figure 3-57 and see the types of goggles used by welders and silver brazers. SPECTACLES are often called "flash goggles." Notice the metal side shields in view A of figure 3-57. This type may have either a rigid, nonadjustable, or adjustable metallic bridge. The other type of goggles is an EYECUP or COVER type, having flexibly connected lens containers shaped to conform to the shape of the face. (See view B of fig. 3-57.) This type is for people who wear glasses.

For hand protection, you may have to use either gauntlet gloves or mitts, such as those shown in figure 3-58. Some of the important safety precautions in working with acetylene and oxygen cylinders are given below. Quite a

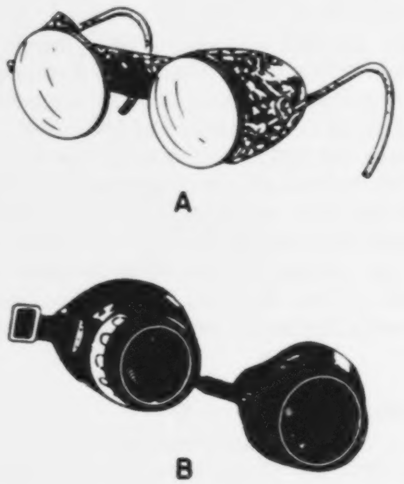


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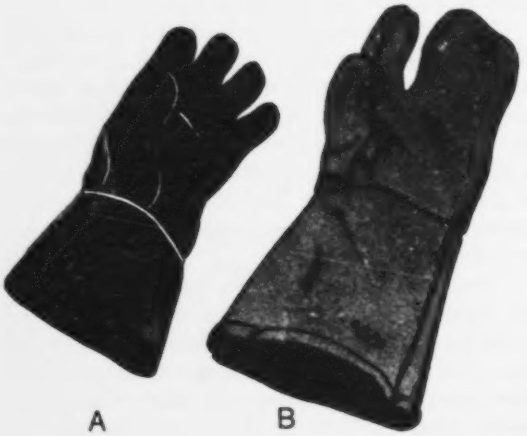
Figure 3-57.—A. Spectacle type of goggles; B. Eyecup or cover type of goggles.



29.201

Figure 3-58.—Gauntlet gloves and mitts.

number of precautions apply to cylinders, so the following precautions should NOT be considered as a complete list of precautions.

Stow all cylinders carefully under prescribed stowage procedures. Cylinders should be stowed in dry, well-ventilated, well-protected places, away from heat, and away from combustible materials. Do NOT stow oxygen cylinders in the same compartment where acetylene or other fuel-gas cylinders are stored. All cylinders should be stowed upright rather than horizontally. If acetylene cylinders are not stowed upright (valves at top), they must not be used until they have been allowed to stand upright for at least 12 hours to prevent acetone discharge. This tendency to discharge acetone depends largely upon the type of porous filler; however, 12 hours is ample time, regardless of the condition of the filler.

When the cylinder is empty, the letter *E* is generally written on the cylinder with a piece of soapstone, keel, or crayon. Stow empty cylinders separately from the charged ones. Stowage spaces must have adequate ventilation and must not be exposed to fire hazards, extremes of weather, continuous dampness, or accumulations of snow or ice.

Galvanized Pipe

The term *galvanized* means that wrought iron and steel pipe are protected to resist corrosion. Wrought iron and steel pipe are made in the same manner. Wrought iron is about twice the cost of galvanized steel, and it is used more for waste systems than for water service. Almost all steel and wrought-iron pipe are galvanized on the outside and on the inside at the factory.

Black iron pipe (not galvanized) is normally cheaper than galvanized pipe. Black iron pipe is suitable for heating (both steam and hot water) and compressed air systems. It is also used for gas and oil pipelines exclusively. Black iron pipe is NOT suitable for use, either in a supply system or a drainage system. This is because black iron pipe rusts and causes stoppages or leaks within a short time.

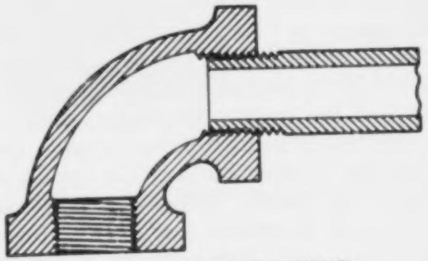
Galvanized wrought iron and steel pipes are cut, measured, and threaded in the same manner. Both types of pipe come in lengths from 18 to 22 feet. The 20-foot length is about average. These pipes are classified into weights, such as standard, heavy, and extra heavy and refer to the wall thickness of the pipe. The wall thickness is a factor that bears directly on the amount of pressure the pipe can withstand.

FITTINGS.—The fittings used on either wrought-iron or steel pipe are generally made of malleable iron or cast iron. There are two types of iron pipe fittings: the pressure type and the recessed type. To compare these two types of fittings, study figure 3-59.

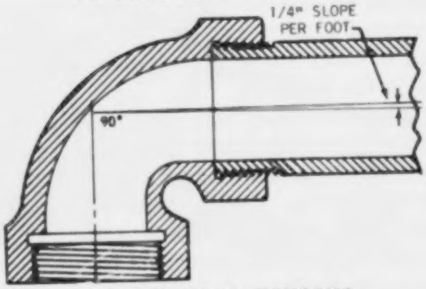
The pressure type of fitting is the standard fitting used on water pipe. The recessed type of fitting, also known as a cast-iron drainage or Durham fitting, is generally required on all drainage lines. The recessed type is most suitable for a smooth joint; it reduces the probability of grease or foreign material remaining in the joint and causing a stoppage in the line. Recessed fittings are designed so horizontal lines entering them have a slope of one-fourth inch per foot.

Types of iron pipe fittings include elbows, crosses, tees, and unions. The four types of elbows are 90-degree, 45-degree, street, and reducing elbows. The 90-degree elbow changes the direction of an iron pipe 90 degrees, and a 45-degree elbow changes the direction 45 degrees.

STREET elbows change the direction of an iron pipeline in a closed space where it would be impossible or impractical to use an elbow and nipple. Both 45- and 90-degree street elbows are



1. PRESSURE FITTING



2. RECESSED FITTING

54.58

Figure 3-59.—Comparison of pressure and recessed (Durham) fittings.

available. Street elbows have one female and one male thread, rather than two female threads.

The REDUCING elbow is similar to the regular 90-degree elbow except that one opening is smaller than the other. For instance, a 3/4-inch pipe can be screwed into one opening of this fitting and a 1/2-inch pipe into the other opening.

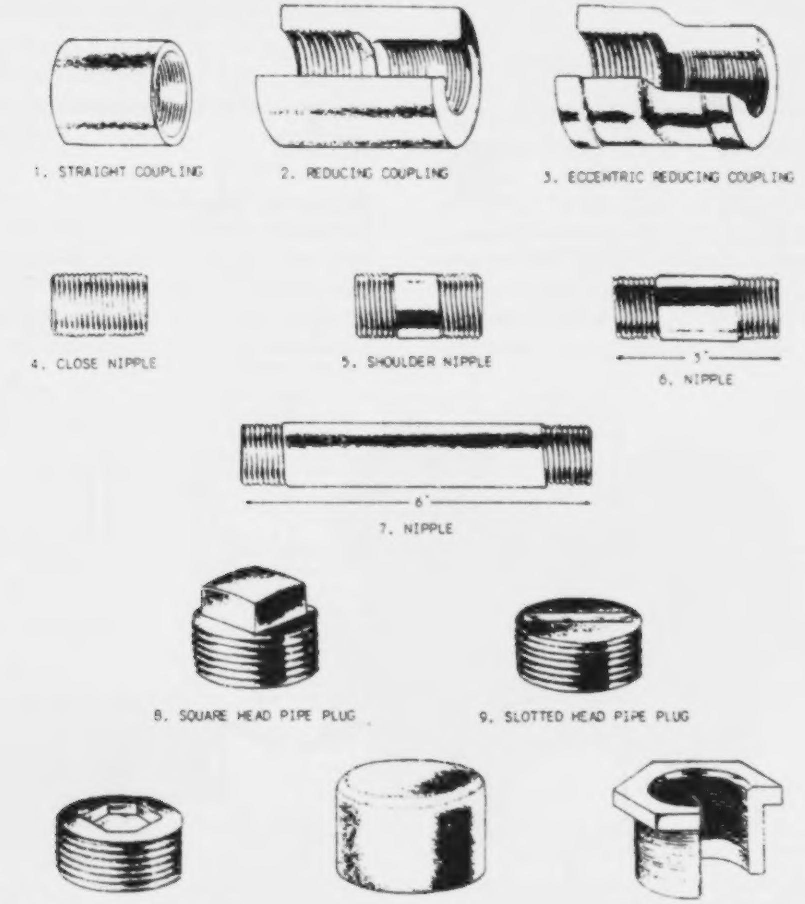
An iron pipe CROSS is made of malleable iron in straight and reducing patterns and has female threads at all four branch points.

A common type of iron pipe tee is the STRAIGHT tee which has a portion that is straight through and a 90-degree takeoff on one side. All three openings of the straight tee are of the same size. Another common type is the REDUCING tee, similar to the straight tee just described, except that one of the threaded openings is of a different size than the others.

There are two types of iron pipe unions. They are the ground joint union and the flange union. The GROUND JOINT union consists of three pieces, and the FLANGE union is made in two parts. Both types are used for joining two pipes together and are designed so they can be disconnected easily.

Other types of iron pipe fittings include couplings, nipples, pipe plugs, pipe caps, and pipe bushings. Each fitting is discussed briefly.

Three common types of couplings are straight coupling, reducer, and eccentric reducer. (See fig. 3-60.) The STRAIGHT COUPLING is for joining two lengths of pipe in a straight run that



1. STRAIGHT COUPLING
2. REDUCING COUPLING
3. ECCENTRIC REDUCING COUPLING
4. CLOSE NIPPLE
5. SHOULDER NIPPLE
6. NIPPLE
7. NIPPLE
8. SQUARE HEAD PIPE PLUG
9. SLOTTED HEAD PIPE PLUG
10. HEXAGON SOCKET PIPE PLUG
11. PIPE CAP
12. PIPE BUSHING

11.311B

Figure 3-60.—Types of iron pipe couplings, nipples, plugs, caps, and bushings.

do not require additional fittings. A REDUCER joins two pipes of different sizes. The ECCENTRIC REDUCER has two female threads of different sizes with different centers so that, when joined, the two pieces of pipe are not in line with each other. It is installed to provide optimum drainage of the line.

A NIPPLE is a short length of pipe (12 inches or less) with a male thread on each end. It is used as an extension for a fitting. In plumbing work, nipples are often used. Nipples are available in many precut sizes. Figure 3-60 shows several common types of nipples.

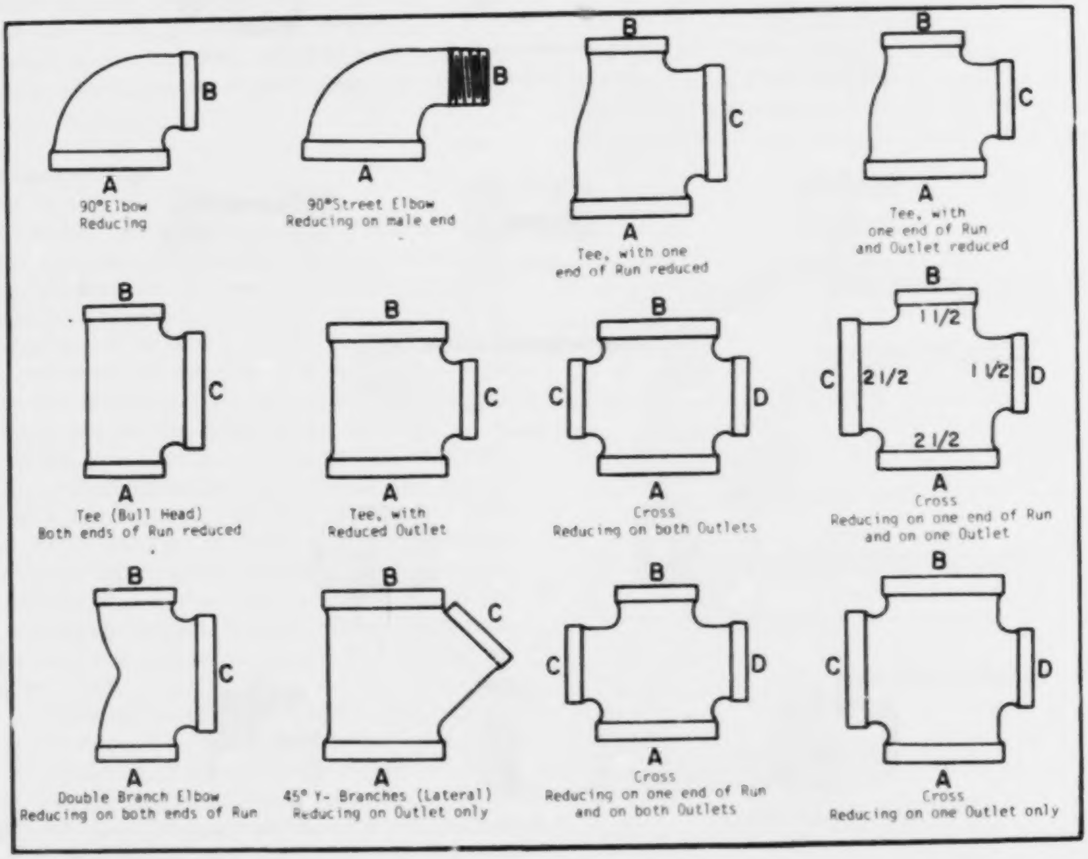
Pipe PLUGS are fittings with male (outside) threads. They are screwed into other fittings to close openings. Pipe plugs have various types of heads, such as square, slotted, and hexagon sockets (fig. 3-60).

A pipe CAP (fig. 3-60) is a fitting with a female (inside) thread. It is used like a plug. It screws on the male thread of a piece of pipe.

A pipe BUSHING is a special fitting with a male thread on the outside and a female thread on the inside (fig. 3-60). Bushings reduce the size of openings of fittings and valves to a smaller diameter.

At times, you may use the DIELECTRIC or INSULATING type of fitting. These fittings connect underground tanks or hot-water tanks. They are also used when pipes of dissimilar metals are joined. The purpose of dielectric fittings is to curtail galvanic or electrolytic action. The most common dielectric fittings are the union, coupling, and bushing.

READING SIZE OF FITTINGS.—To help you read the designations of fittings, you should


B
A
90°Elbow
Reducing
B
A
90°Street Elbow
Reducing on male end
B
C
A
Tee, with one
end of Run reduced
B
C
A
Tee, with
one end of Run
and Outlet reduced
B
C
A
Tee (Bull Head)
Both ends of Run reduced
B
C
A
Tee, with
Reduced Outlet
B
C
D
A
Cross
Reducing on both Outlets
B
1 1/2
C
2 1/2
1 1/2
D
2 1/2
A
Cross
Reducing on one end of Run
and on one Outlet
B
C
A
Double Branch Elbow
Reducing on both ends of Run
B
C
A
45° Y- Branches (Lateral)
Reducing on Outlet only
B
C
D
A
Cross
Reducing on one end of Run
and on both Outlets
B
C
D
A
Cross
Reducing on one Outlet only

11.310

Figure 3-61.—How to read measurements of fittings.

know that each opening of the fitting is identified with a letter that indicates the sequence in reading the size of the fitting. As shown in figure 3-61, a cross with one end of run and one outlet reduced is designated as 2 1/2(A) × 1 1/2(B) × 2 1/2(C) × 1 1/2(D). This is done simply by naming the largest opening first and then naming the other openings in the order indicated.

Elbows and crosses are always identified by designating the size of the largest opening first, following with the size of the other openings in proper order. Tees, 45-degree Y-branches, and double-branch elbows are identified by designating the size of the largest opening on the run first, the opposite opening of the run second, and the size of the outlet last. For example, a 3 × 2 × 1 1/2 size tee is one that has openings 3(A) × 2(B) × 1 1/2(C). In designating the outlets of side outlet reducing fittings, the size of the side outlet is named last. Refer to figure 3-61. The rules for reading screwed fittings also apply to reading other reduced fittings.

MEASURING.—Galvanized steel, galvanized wrought iron, and black iron pipe are measured for size by the INSIDE diameter of the pipe. The outside diameter of the pipe remains constant for the different weights; whereas the inside diameter of the pipe varies because of the wall thickness of the pipe. The outside diameter is held constant because the pipe is normally joined by threaded joints, and one die can be used to thread any weight of one size. Also, fittings of a uniform size on the inside fit all the different weights of pipe. Threaded galvanized or black iron pipe is measured like copper pipe and tubing, as shown in figure 3-41.

CUTTING, REAMING, AND THREADING.—Galvanized pipe can be cut, reamed, and threaded by hand or with a power-operated machine. This discussion is limited to cutting, reaming, and threading pipe with a power-operated machine. A power-operated machine saves times, especially when a large volume of material has to be cut. A typical electrically operated pipe machine (drive) is shown in figure 3-62.

In cutting galvanized pipe with the machine shown in the figure, insert the pipe into the machine. Then tighten the chuck jaws and rear centering jaws. Put the tool support bar in a position to support the cutter handle. Next, apply the cutter to the pipe as if you were cutting it manually. Let the cutter handle rest on the tool support bar. Ensure the cutter wheel is exactly on the mark where the pipe is to be cut. Now, tighten the cutter blade so it contacts the pipe. The next step is to turn the power switch to the

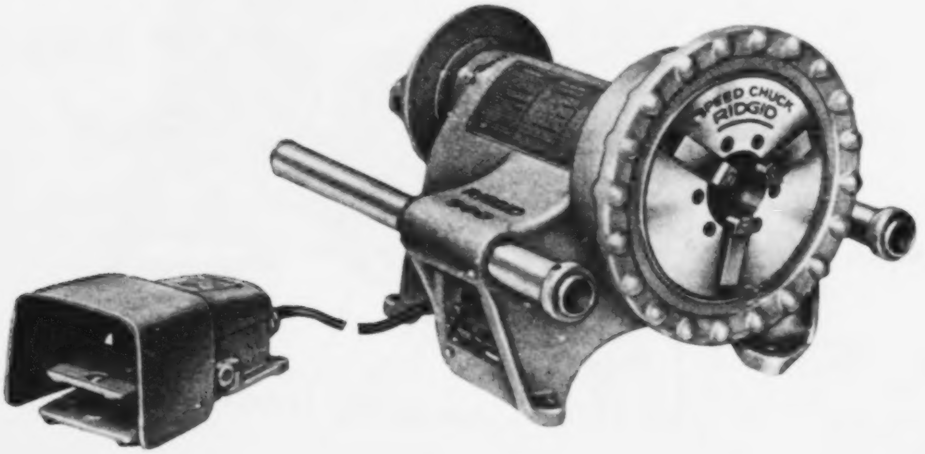


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Figure 3-62.—Electrically operated pipe (drive) machine.

FORWARD position. Continue turning the cutter blade into the pipe until the cut is completed.

After the pipe has been cut, it can be reamed with the same machine. To ream the pipe, place the reamer in the pipe end. Let the handle of the reamer rest against the tool support bar. Turn on the motor. Press the reamer into the pipe as needed to remove the burr.

The machine can also be used for threading pipe. First, insert the pipe into the front or the rear of the machine. Let the pipe extend out of the speed chuck far enough so the threader clears the chuck during threading. Next, center the pipe in the speed chuck and close the jaws with a snap-spin of the handwheel. If the pipe extends out the back of the machine, close the rear centering jaws. Then place the threader on the pipe in the usual way. Pull out the tool support bar to the desired position and allow the threader handle to rest on the tool support bar on the switch side. Hook the safety latch over the handle. Now turn on the switch and proceed to thread the pipe. During the threading operation, remember to use plenty of cutting oil. In addition to the machine shown in figure 3-62, figures 3-63 and 3-64 show other types of power pipe machines and their accessories.

JOINING.—THREADED PIPE JOINTS are commonly used on galvanized steel, galvanized wrought iron, and black iron pipe. This method of pipe joining involves connecting threaded male and female ends.

To obtain a tight threaded joint, be sure the threads are clean and in good condition. If the pipe has been exposed to the weather or banged around, check the threads carefully. If necessary, run a die over the threads to straighten the damage.

After securing the pipe in a vise, you must clean both ends with a wire brush. Then, apply a good thread lubricant on the male pipe threads. You should always use a Navy-approved nontoxic compound for water pipes and mixed powdered graphite and oil for steam pipes. Do not apply pipe dope inside the pipe fitting, or you will foul the system.

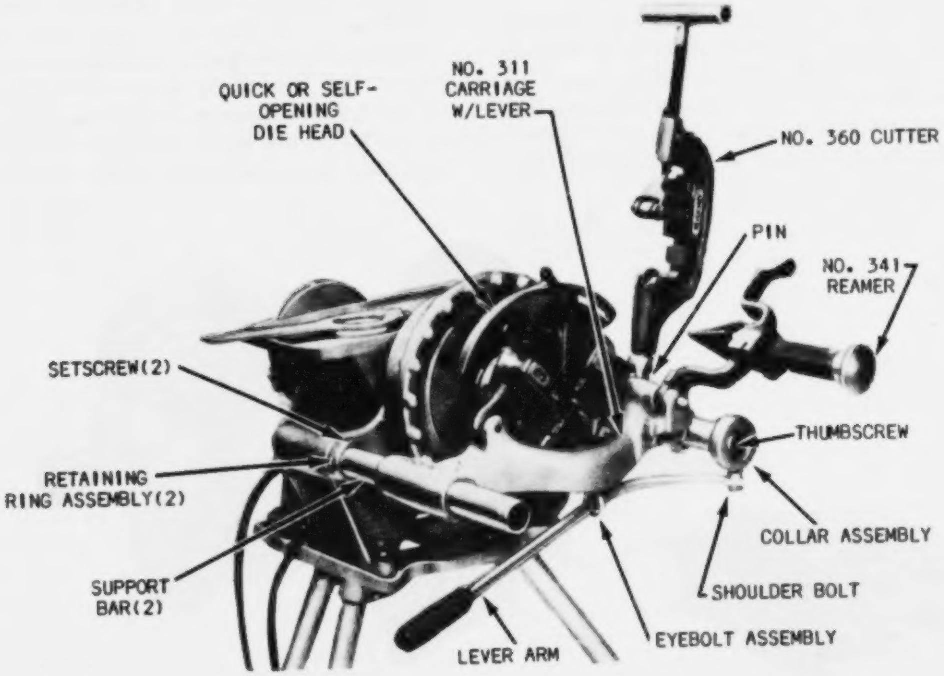

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Figure 3-63.—Ridgid 300 power drive with accessories.

Start the joint by hand and turn it up as far as you feel it will go. Now, slowly screw the remaining section of the pipe into the joint and tighten it with a pipe wrench. Do not use a hickey, or oversized wrench, or too much pull. Not all of the male threads should be screwed into the joint. If all the threads are used, the wedging action of the tapered thread may cause the fittings to split. Usually there are two or three unused threads on a properly threaded pipe. If you follow the above steps and the threads are made properly, the joints will be tight for pressures several times the 150-psi working pressure of the fittings.

Cement-Asbestos Pipe

Cement-asbestos pipe is corrosion resistant and does not rust or rot. It has a smooth interior surface that is a favorable friction factor. This pipe comes in sizes from 3 to 36 inches in diameter for pressures of 50 to 200 psi and in lengths of 5, 10, and 13 feet. Light in weight, cement-asbestos pipe is easy to handle. It is made with beveled ends, and adapters are available for connecting to pipe made of other materials.

CUTTING.—Cement-asbestos pipe can be cut to any length or angle with a carpenter's saw or a transite pipe cutter. Or, it can be tapped for threaded service connections by using a water main self-tapping machine. With this machine the pipe can be tapped, threaded, and a corporation stop installed while the pipe is under water pressure.

SAFETY EQUIPMENT AND PROCEDURES FOR CUTTING CEMENT-ASBESTOS PIPE.—Because of the health and environmental hazards associated with cement-asbestos pipe, special cutting and handling kits have been procured by the Navy and are available through the naval supply system. Whenever cement-asbestos pipe is encountered, the base or unit environmental officer should be contacted. Also, the newest and most up-to-date instructions should be obtained and followed. Since safety procedures governing asbestos-related equipment

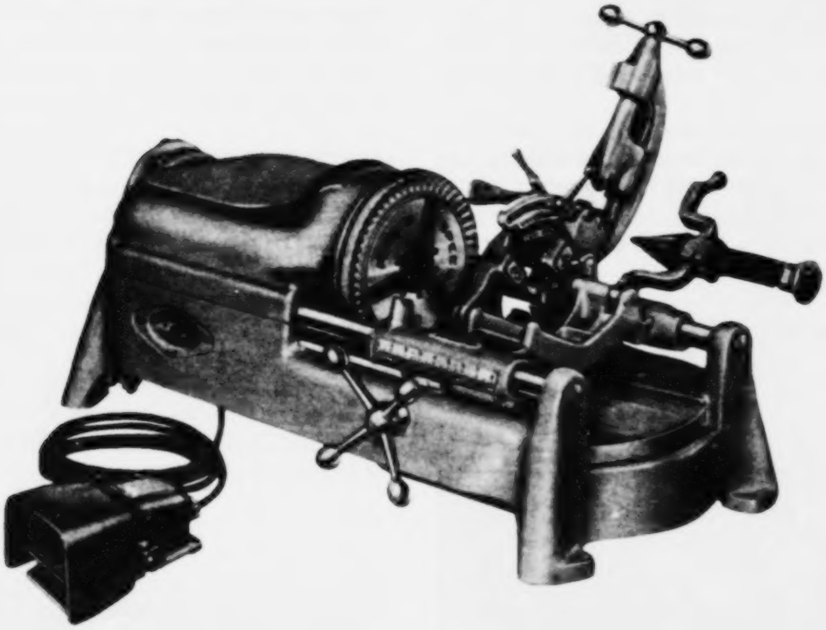

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Figure 3-64.—Ridgid 535 pipe- and bolt-threading machine.

are continually changing, an attempt to outline all the pertinent procedures for working with asbestos are not included in this manual. However, there are two important factors you should keep in mind. First, always wear a breathing filter or mask. Second, use water while cutting to keep the dust from becoming airborne, or use a vacuum to pull dust from the area of the cutting tool.

FITTINGS.—In the absence of cement-asbestos fittings, you can use double-bell, cast-iron fittings and make them up as you would with cast-iron pipe, using sulfur compounds or lead.

JOINING.—Joints in cement-asbestos pipe are commonly made with a special coupling with three rubber sealing rings. Three rings are fixed in grooves at the factory, ready for assembly.

Figure 3-65 shows a cutaway view of a completed joint with the three rings in proper position. As each pipe moves into position during assembly, the rubber rings in the two outer grooves of the coupling are compressed to seal the joint tightly. The T-shaped center ring forms a seal between the pipe ends to eliminate jogs and pockets and to provide for uninterrupted flow. In this type of joint, you have a tight and flexible connection.

A joint like the one shown in the figure can be assembled entirely by hand. After making sure the rings in the grooves of the coupling are in correct position, use the following two-step procedure, shown in figure 3-66, to make the connection.

1. Apply a thorough coating of lubricant to the male end of the pipe, all the way around. (See view A, fig. 3-66.) If a special lubricant supplied by the manufacturer is not available, prepare a jellylike soap solution instead.

2. Pull or push the pipe together, as indicated in view B of figure 3-66, and the joint is complete.

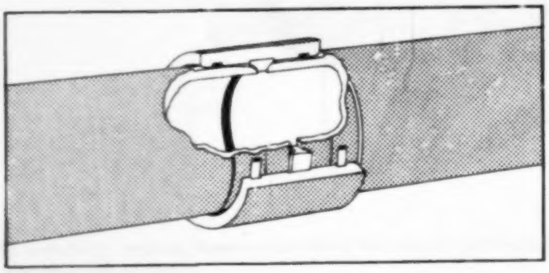

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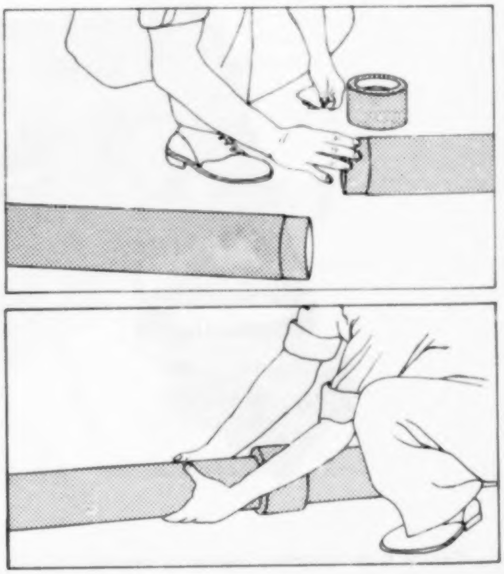
Figure 3-65.—Cutaway view of a cement-asbestos pipe joint.

Ductile Iron

Ductile iron is cast iron in which the carbon is reformed by magnesium inoculation. This results in exceptional strength characteristics without otherwise changing the basic nature of the cast iron. Because of this treatment ductile iron has exceptional strength with good machinability, high impact, corrosion resistance, and great beam strength. For these reasons, ductile iron pipe is ideal for transportation of water.

When laying this pipe, you should ensure that both the bell and plain ends are clean. This is to prevent leaking joints. Sand, dirt, excess coating, ice, and other foreign material should be carefully removed from the plain end and the interior of the bell. This will ensure proper seating of the gasket and correct entry of the plain end into the bell socket. The direction of the bells is not functionally related to the direction of water flow within the pipe.



54.51

Figure 3-66.—Steps in assembling a cement-asbestos pipe joint.

The mechanical joint for ductile iron pipe has four parts: a flange cast integrally with the bell of the pipe; a rubber gasket fitting a recess in the socket; a gland, or follower ring, to compress the gasket; and bolts and nuts for tightening the joint. The assembly of the joint is very simple and requires only the use of a wrench to tighten the nuts.

If the pipe must be cut, it may be cut by using an abrasive wheel, a rotary wheel cutter, a guillotine pipe saw, a milling wheel saw, or an oxyacetylene torch. Of these cutting tools, the abrasive wheel saw is most frequently used for out of trench cuts; while the oxyacetylene torch method is used most frequently in trench cuts. Cut ends and rough edges should be ground smooth. For push-on type connections, the cut end should be slightly beveled.

Because of the high-impact strength of ductile iron, you only need to remove rocks and boulders 8 inches or greater in diameter from the material to be used as backfill.

PVC Class Water Pipe

PVC class water pipe is used for construction projects around the world. It is light in weight compared to similar size iron pipe, and it can be easily cut and beveled with cement-asbestos tools. Most importantly, PVC class water pipe can be easily joined together.

When installing this type of pipe, ensure the bell end, the plain end, and the gasket are free of dirt and debris. Usually, the company supplying the pipe also supplies a lubricant to facilitate the sliding of pipes together. When backfilling, ensure there are no rocks or other hard debris in the backfill material, as they could, over a period of time, puncture the pipe.

One of the best reasons for using PVC pipe in a water main is the ease with which it can be tapped. There is also a variety of adapters and valves readily available in the naval supply system.

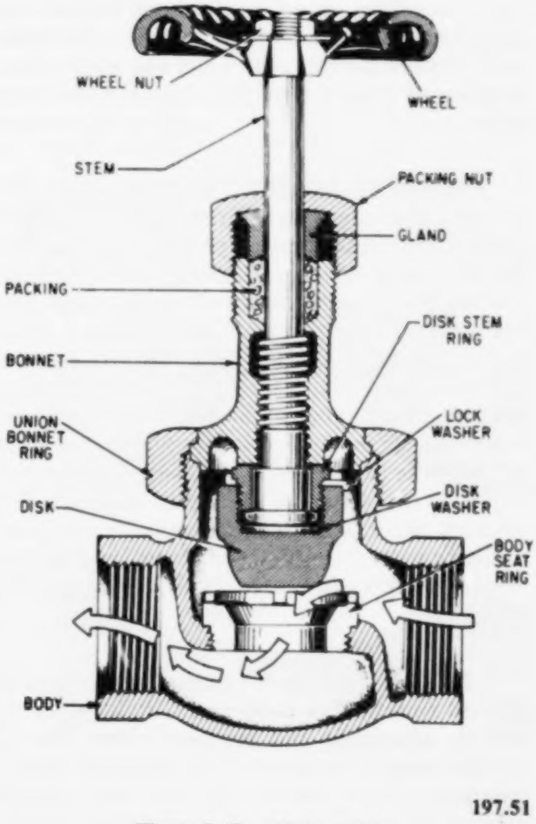
Types of Valves

Flexibility in the operation of a water-supply system requires the proper valves for the condition to be controlled. Aside from completely stopping the flow, valves throttle or control quantities of water flowing in a pipeline. Other uses include pressure and level control and proportioning flow. A wide variety of valve designs are available. A number of different types of valves used by the UT are discussed in the following paragraphs.

GLOBE VALVES.—So-called because of their globular outline, globe valves are used for control of liquids, gases, and vapors by means of throttling. They are well suited for services requiring regulated flow. (See fig. 3-67.) The closure disk and seats increase resistance to flow and permit close regulation of flow. The fluid flow is proportionate to the number of turns of the wheel in opening or closing the globe valve. The globe valve is ideal for service that requires frequent valve settings (throttling).

Globe valves can be fitted with fiber disks suitable for almost any type of service. When steam is used as the service, you should use metal disks instead of fiber disks. The globe valve is designed to minimize erosion, in which case lower maintenance costs are likely where a wide range of flow is desired. But, operating costs may be greater since globe valves offer more resistance to flow than a gate valve and cut down line pressure.

An ANGLE valve is a globe valve in which the path of flow is changed 90 degrees to the



197.51

Figure 3-67.—Globe valve.

inlet. (See fig. 3-68.) The resistance to flow through an angle valve is less than that through an elbow and a straight globe valve.

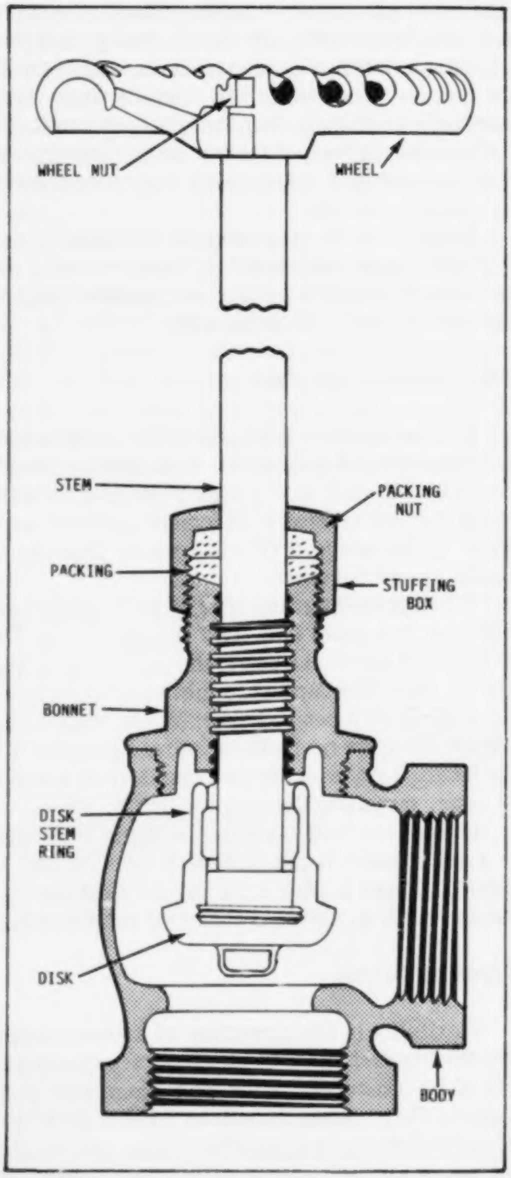
PRESSURE-REDUCING VALVES.—These are automatic valves that reduce the supply pressure to a specified lower discharge pressure. The pressure-reducing valve can be set for any desired discharge pressure within the design limits of the valve. After the valve has been set, the reduced pressure is maintained regardless of changes in the supply pressure (as long as the supply pressure is at least as high as the desired delivery pressure), and regardless of the amount of reduced pressure fluid being used.

Various types of pressure-reducing valves are available. Figure 3-69 shows a spring-loaded pressure-reducing valve. In this valve, water enters on the inlet side and acts against the main valve disk, tending to close the main valve. However, water pressure is also led through ports to the auxiliary valve, which controls the admission of water pressure to the top of the main valve piston. This piston has a larger surface than the main disk; therefore, a relatively small amount of pressure acting on the top of the main valve piston tends to open the main valve and also allows water at reduced pressure to flow out the discharge side.

PRESSURE-RELIEF VALVES.—This type of valve discharges water from pipes or systems when a maximum desired pressure is exceeded. Pressure-relief valves are installed on low-pressure systems fed through pressure-reducing valves from high-pressure supplies to ensure against damage if the pressure-reducing valves fail to operate. Pressure-relief valves are also used on pump headers, discharging into large supply mains to relieve the high-surge pressure which builds up between the time a pump is started and the time required for water in the main to reach full velocity. Relief valves are essentially pressure-reducing valves in which the control mechanism responds to pressure on the inlet, rather than the outlet, end.

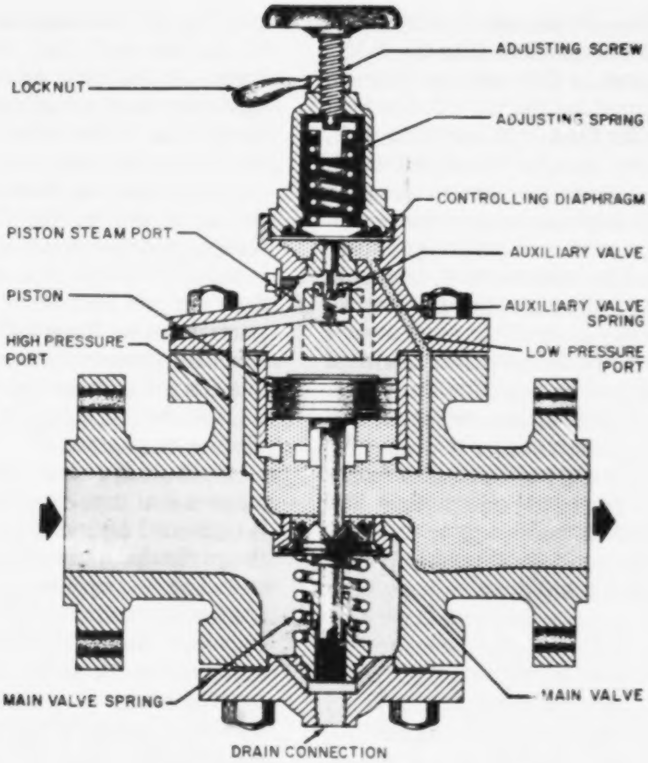
CHECK VALVES.—These valves are used to prevent backflow in pipelines. Check valves are entirely automatic and are used where flow of liquids, vapors, or gases in one direction only is required. Check valves fall into two general groups: lift check valves and swing check valves.

A LIFT CHECK valve is usually used for air or gases, or when operation of the check valve is very frequent. (See fig. 3-70.) A SWING CHECK valve is usually used where full flow is desired and should be installed so the disk is held to the seat and closes by gravity. (See fig. 3-71.) Lift check valves seat more positively and tightly than swing check valves. The disk is seated by backflow, or by gravity when there is no flow.



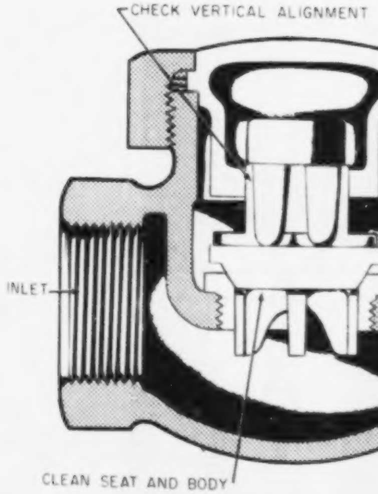
54.53

Figure 3-68.—Angle valve.


ADJUSTING SCREW
LOCKNUT
ADJUSTING SPRING
CONTROLLING DIAPHRAGM
PISTON STEAM PORT
AUXILIARY VALVE
PISTON
AUXILIARY VALVE SPRING
HIGH PRESSURE PORT
LOW PRESSURE PORT
MAIN VALVE SPRING
MAIN VALVE
DRAIN CONNECTION

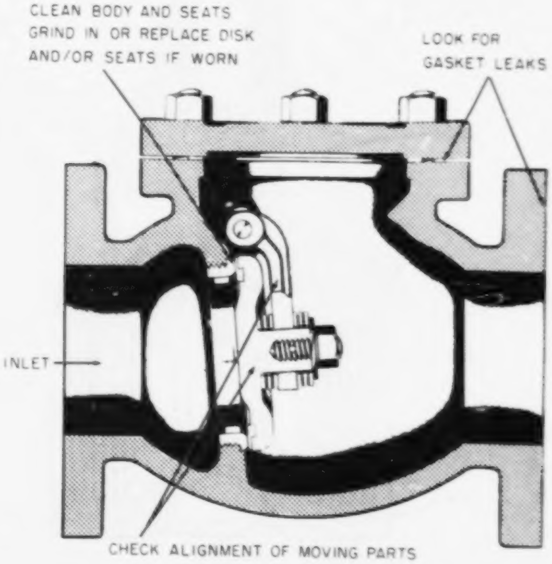
47.59

Figure 3-69.—Spring-loaded pressure-reducing valve.


CHECK VERTICAL ALIGNMENT
INLET
CLEAN SEAT AND BODY

11.320

Figure 3-70.—Lift check valve.


CLEAN BODY AND SEATS
GRIND IN OR REPLACE DISK
AND/OR SEATS IF WORN
LOOK FOR
GASKET LEAKS
INLET
CHECK ALIGNMENT OF MOVING PARTS

11.319

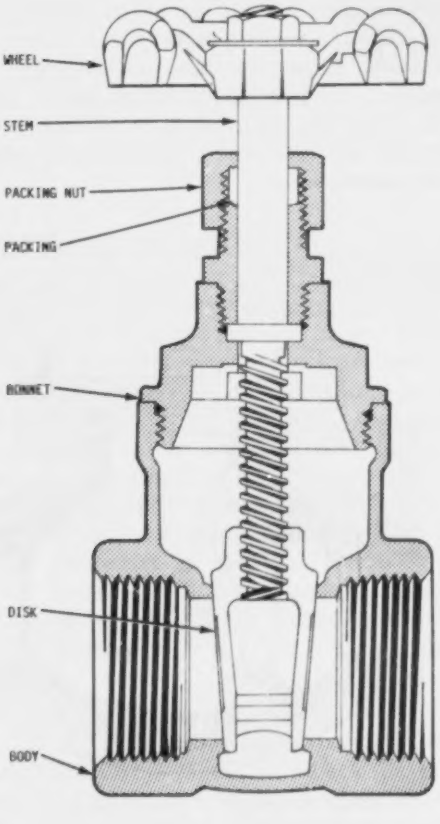
Figure 3-71.—Swing check valve.

GATE VALVES.—These valves allow fluid to flow through in a straight line. (See fig. 3-72.) There is little resistance to flow and less friction and pressure drop, provided the valve disk is kept fully opened or fully closed. A gatelike disk, moved by a stem screw attached to a handwheel, moves up and down at right angles to the path of flow. The gate valve releases a variable amount with each turn. The second turn may release three times as much as the first, and the third, five times as much. When closed, the gate seats against two seat faces to stop flow. Gate valves must always be operated in either their fully opened or closed position and should not be used for throttling. A partly closed gate valve causes vibration and chattering, damaging the seating surfaces.

When gate valves are opened and closed only at infrequent times, they last a long time and require little maintenance. If a gate valve is operated over 10 times a day, everyday, it will quickly wear out, and a globe valve should be substituted. The wear is on the downstream faces of the seat and disk, because the line pressure forces all the wear on these surfaces. Since the upstream faces are seldom damaged in this way, longer life of the valve can result if worn gate valves are reversed.

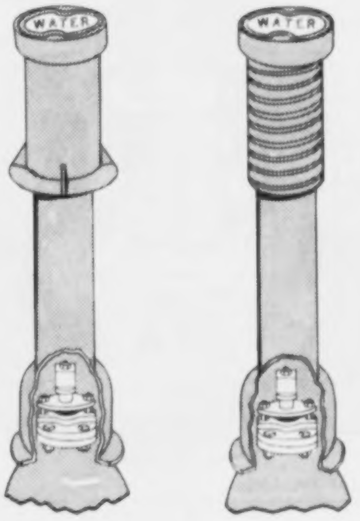
Four types of disks are used in gate valves: the solid wedge, the flexible wedge, the split wedge, and the double disk. The most popular is the solid-wedge disk, a single moving part that does not jam because of misalignment of mating parts, whether the stem is up, sidewise, or down. Ideal for steam service and well suited for water and for many other fluids, it is also the best type of disk for turbulent flow because it does not vibrate or chatter.

Split-wedge and double-disk valves have wedges that come in several parts. As the valve is tightened after closure, the wedge or spreader forces the disk outward and hard against the body seat. The first opening turn releases the disks, and continual turning raises them clear of the seat openings. Such parallel seats can be repaired or replaced easier than those accommodating a tapered-wedge disk. Double disks cannot always be used. To assure proper closure, do not install a double-disk valve with its stem below horizontal, since it is apt to vibrate in steam service and cause the disk and seats to wear too fast. However, the valve is good in pipelines conveying liquids or noncondensing gases at normal temperatures.



54.200

Figure 3-72.—Gate valve.



54.201

Figure 3-73.—Valve boxes.

Valve Operation and Installation

Valve operation and installation are a significant part of the Utilitiesman rating. In this section the proper way of opening and closing valves and the uses of accessory apparatus, such as valve boxes, floor stands, and post indicators, are discussed. General instructions on how to install valves in a water-supply system are also provided.

VALVE OPERATION.—When valves are operated manually, there are several sound rules to follow. In manually opening a valve, it should be opened all the way, then closed one-quarter turn of the handwheel. This step prevents the valve from sticking in the open position. Valves should be opened slowly and at an even rate to reduce the hazard of water hammer. Unless otherwise indicated, valves are opened by turning the handwheel counterclockwise. Always consult the manufacturer's instructions for the operation of a particular type of valve.

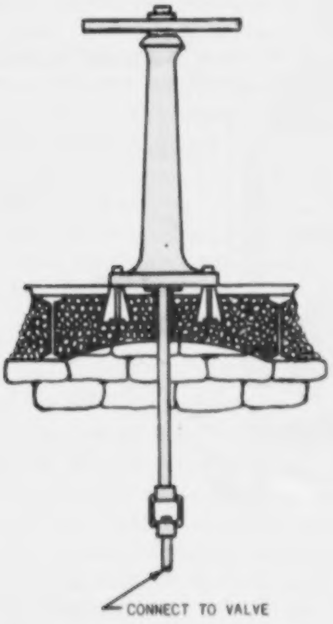
Many valves in water-supply systems are power operated and require little operating attention, except during a power failure. To close or open such a valve manually, you should consult the manufacturer's instructions. Most power-operated valves are equipped with safety devices to allow for such operation.

ACCESSORY APPARATUS.—Accessories that aid in the control of valves include valve boxes, floor stands, and post indicators. Each of these supporting materials is discussed briefly below.

Street valves must be accessible for turning off and on; and, with large valves, the entire valve should be accessible for servicing. For the first purpose, valve boxes (fig. 3-73) are used, and for the second, vaults or manholes are used. Since valves are placed at various depths, valve boxes are made in two or more pieces which telescope to give adjustable lengths.

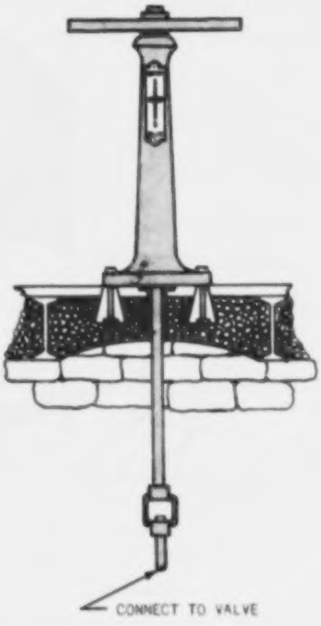
Valve controls may be mounted on floor stands for operating valves below a floor. They are operated manually by turning the handwheel, or by automatic controls. Some floor stands are equipped with indicators to show when the valves are opened or closed. Floor stands (fig. 3-74) are essentially an extension of the valve stem.

Post indicators (fig. 3-75) provide for operating nonrising-stem gate valves placed below the ground or floor level. They are used



54.202

Figure 3-74.—Floor stand.



54.203

Figure 3-75.—Floor stand with post indicator.

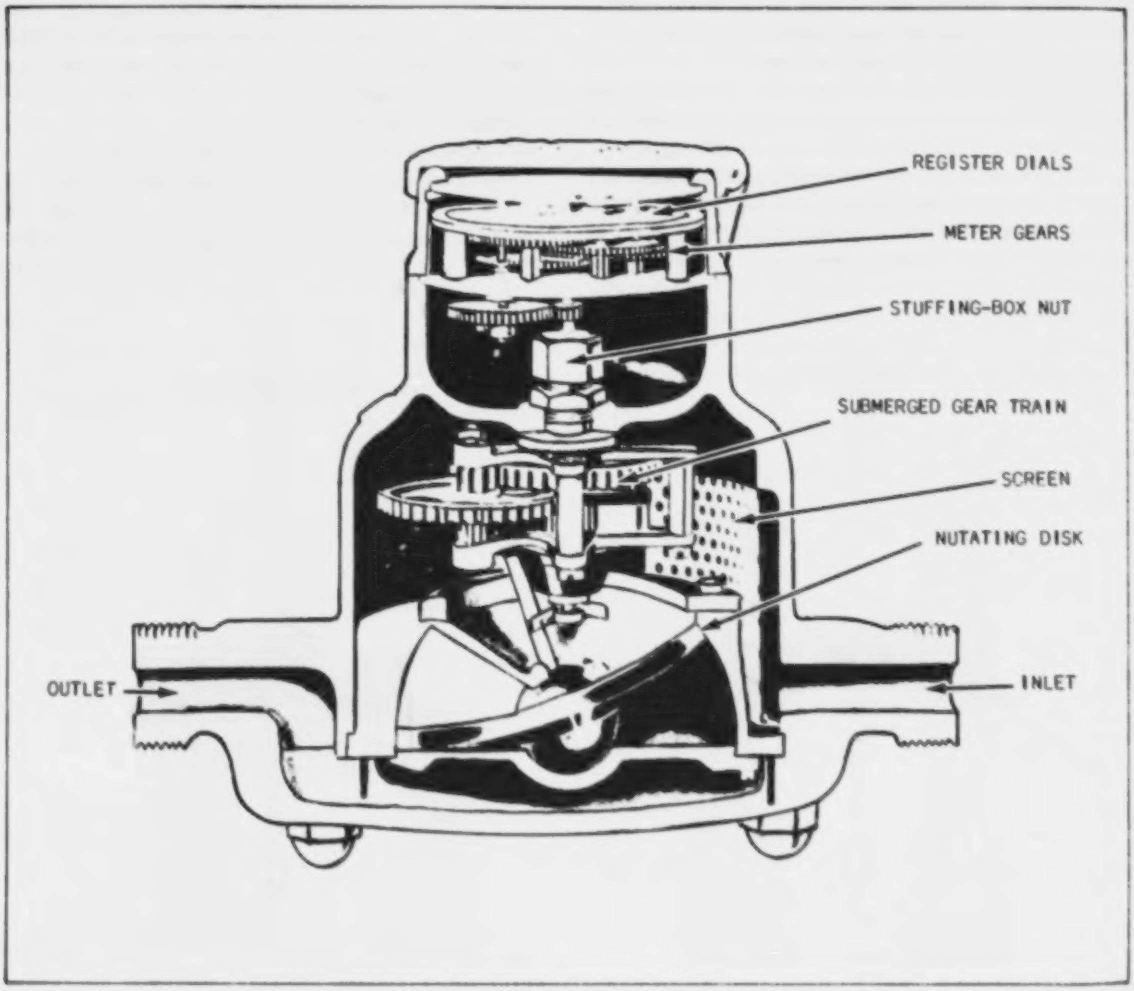
principally in fire-flow systems, and in this function must be fully approved by the Underwriters' Laboratories and the Associated Factory Manual Fire Insurance Companies (indicated on the post by the letters UA and FM). The indicator post is operated by an attached vise, when not in use. The valve is opened by turning the wrench to the left, unless otherwise indicated. The open or closed position of the valve is clearly indicated by the target places which show the words *Open* and *Shut* in glass protected openings on both sides of the post. Most post indicators are sealed open for safety. If the seal has been broken, the operator should report this condition to higher authority immediately.

VALVE INSTALLATION.—As a Utilitiesman, you have to install various types of valves. Some general instructions that usually apply when installing valves in a water-supply system are given below.

Valves should be handled carefully. If a valve is dropped, a part vital to dependable operation may break or become deformed.

Valves should not be located where they are exposed to damage from blows. They should be accessible, and it should be possible to open them fully. Valves should not be installed where they must carry the weight, sag, or expansion of a line.

It is important that valves be in the closed position during installation. In the closed position,



38.64

Figure 3-76.—Nutating-disk meter.

operating parts are less likely to become twisted, and the areas of closure are protected.

Overlength threading should be avoided on the joining pipe, so the end of the pipe does not project into the valve and injure the valve seat.

Sealing compound should be applied only to the pipe threads, and care should be taken so the compound does not get into the valve and injure the seat.

The pipe should be cleaned before a valve is installed and blown out again with compressed air (if necessary) after installation.

In attaching a valve, use a wrench on the hex nut nearest the pipe to which the valve is being connected.

The packing in a new valve should be tightened after it has been in used for a short time, but it should not be allowed to become tightly compressed.

The general instructions above may not apply to the installation of all types of valves. For specific instructions, follow the recommendations of the manufacturer of the valve being installed.

WATER METERS

Water meters measure the flow of water within a line to a point of distribution, such as laundries, housing areas, and so on. There are various types of water meters. One type is the disk type of volume meter. This water meter is used chiefly for services supplied through pipes less than 1 1/2 inches in diameter, although water meters are made in sizes up to 6 inches.

Figure 3-76 shows the nutating-disk type of volume meter. This type is mainly used for individual service connections as it is accurate for very low flows. Flows above normal cause rapid wear. The disk type of meter contains a measuring chamber of definite content in which a disk is actuated by the passage of water. Each cycle of motion of the disk marks the discharge of the contents of the measuring chamber. By means of gearing, the motion of the disk is translated into units of water volume on the register dial.

When installing a water meter, make sure it is horizontal and that it operates under back pressure. The meter is normally located near the pressure-reducing valve at underground level; so in freezing temperatures, ensure the meter is protected from exposure.

Water is measured in terms of rate-of-flow (volume passing in a unit time), or total volume. Units and equivalents usually are as follows:

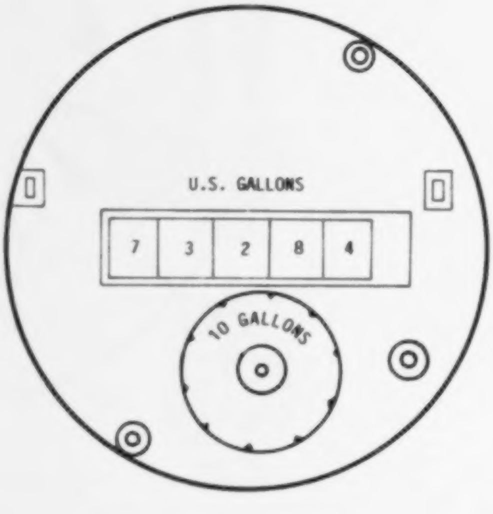
Unit	Equivalent
Cubic feet per second (cfs)	448.83 gallons per minute (gpm)
cfs	646,315 gallons per day (gpd)
gpm	0.00223 cfs
gpm	1,440 gpd
Million gallons per day (mgd)	1.547 cfs
mgd	694.4 gpm
cu ft	7.48 gal

IN READING A METER, YOU SHOULD FIRST DETERMINE WHETHER IT IS MEASURING THE WATER FLOW IN CUBIC FEET OR IN GALLONS.

Meter Dials

There are two general types of meter dials: the straight-reading type and the circular-reading type. Each type is discussed in the following paragraphs.

The STRAIGHT-READING DIAL, shown in figure 3-77, may be read in the same way as



54.204

Figure 3-77.—Straight-reading meter dial.

mileage on an automobile. When the meter register has one or more fixed zeros, always be sure to read them in addition to the other numerals.

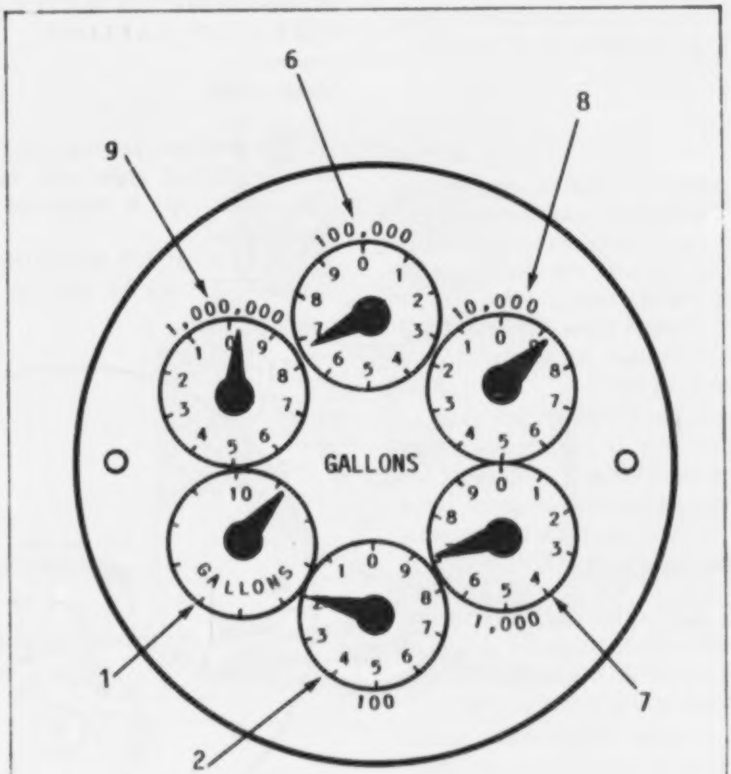
In the CIRCULAR-READING DIAL, when the hand on a scale is between two numbers, the lower number is read. If the hand seems exactly on the number, check the hand on the next lower scale. If that is on the "1" side of zero, read the number on which the hand lies; otherwise, read the next lower number. The procedure for reading the circular-reading dial, shown in gallons in figure 3-78, is to begin with the "1,000,000" circle and read clockwise to the "10" circle, the scales registering 7, 6, 4, 3, 3, and 5, respectively, making a total of 764,335 gallons.

Obtaining Current Reading

Since the registers are never reset while the meters are in service, the amounts recorded for any period of time must be determined by subtraction. To obtain a current reading, subtract the last recorded reading from the current dial reading. Remember, the maximum amount that can be indicated on the usual line meter before it turns to zeros and begins all over again is 99,999 cubic feet, or 999,999 gallons. Thus, to obtain a current measurement when the reading is lower than the last previous one, add 100,000 to the present reading on a cubic feet meter, or 1,000,000 to the present reading on a gallon meter. The small denomination scale, giving fractions of one cubic foot or ten gallons, is disregarded in the regular reading. It is used for testing only.

FIRE HYDRANTS

The fire department (or safety office) is responsible for the selection and use of



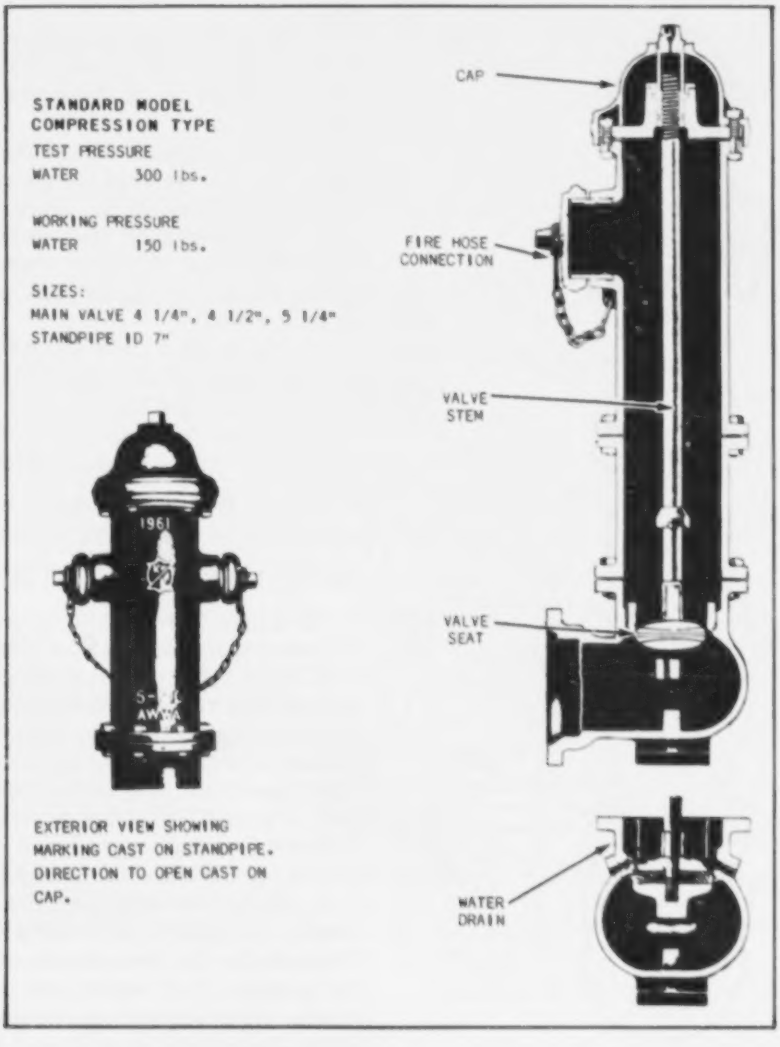
61.13

Figure 3-78.—Reading the circular-reading meter dial in gallons.

fire-fighting equipment, including fire hydrants. It is a responsibility of the Utilitiesman to ensure water is available to the hydrant and that control valves operate properly.

Most fire hydrants consist of a cast-iron barrel with a bell or flange fitting at the bottom to connect to a branch from the main; a valve of the gate or compression type, with a long stem terminating in a nut above the barrel; and one or more outlets. There are many designs of fire hydrants, two of which are the DRY-BARREL HYDRANT and the WET-BARREL HYDRANT.

In cold climates, where freezing occurs, dry-barrel hydrants are used. (See fig. 3-79.) With this type of hydrant, the drain valve or weep hole must be kept open in all systems where the groundwater level is below the hydrant foot so that the barrel can drain and not freeze in cold weather. A box placed over a hydrant affords some protection against freezing and leaves the top of the hydrant free of snow and ice. The hydrant is equipped with two 2 1/2-inch hose outlets and a 4 1/2-inch pumper outlet whose threads conform exactly to the standards specified in


STANDARD MODEL
COMPRESSION TYPE
TEST PRESSURE
WATER 300 lbs.
WORKING PRESSURE
WATER 150 lbs.
SIZES:
MAIN VALVE 4 1/4", 4 1/2", 5 1/4"
STANDPIPE ID 7"
1961
AWWA
EXTERIOR VIEW SHOWING MARKING CAST ON STANDPIPE. DIRECTION TO OPEN CAST ON CAP.
CAP
FIRE HOSE CONNECTION
VALVE STEM
VALVE SEAT
WATER DRAIN

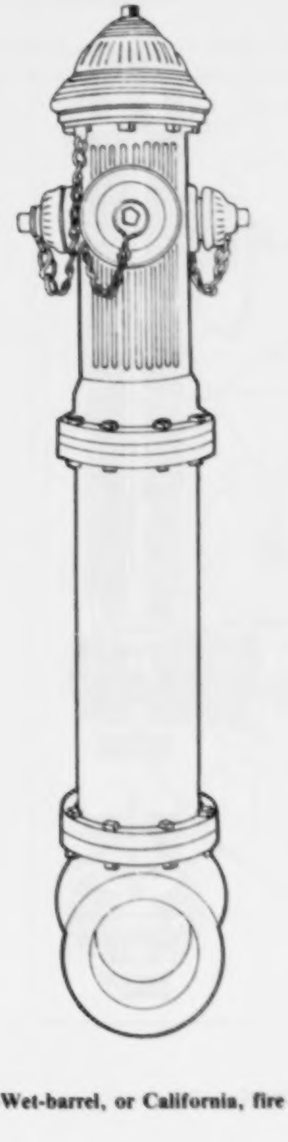
54.205

Figure 3-79.—Dry-barrel fire hydrant.

Screw Threads and Gaskets for Fire Hose Connections, NFPA, 1963.

Where freezing temperatures do not occur, use wet-barrel (or California) hydrants. (See fig. 3-80.) With this type of hydrant, all the packing glands should be kept in good condition to prevent leakage as well as to allow free operation of the stem controlling each outlet. Valve seats for wet-barrel hydrants afford easy access for inspection.

Hydrants exposed to traffic hazards must be protected by appropriate guards. Most damage is caused by an accident or by improper or careless operation. Much of this can be prevented if operating personnel are made to realize that a properly functioning fire hydrant is critical to the protection of life and property at the activity. Without much extra labor or effort, operating personnel can take several precautions to keep the hydrant structure in good condition. General precautions are listed below.



54.206

Figure 3-80.—Wet-barrel, or California, fire hydrant.

1. The operation of fire hydrants should be restricted to responsible personnel ONLY, trained in this and allied work, such as fire fighters, utility maintenance, and operating personnel.
2. For opening and closing the hydrant, use ONLY an approved hydrant wrench. The reason is that ordinary wrenches can ruin the operating nut.
3. Keep the hydrant drained when it is not in use. This is particularly important in cold climates where ice in the hydrant may make it inoperative.
4. Pipes should be connected only to draw off water for fire-fighting purposes, except in an emergency. Any such connection must be removed immediately after an emergency. Connections made to provide a temporary supply for vehicle washing, irrigation, and so on, should not be permitted.
5. The hydrant valve should be kept in either the wide open or fully closed position and never used to throttle the flow of water. If it is necessary to restrict the flow, separate globe valves should be attached to the hydrant discharge outlet.

Figure 3-81 shows the proper method of installing and supporting fire hydrants.

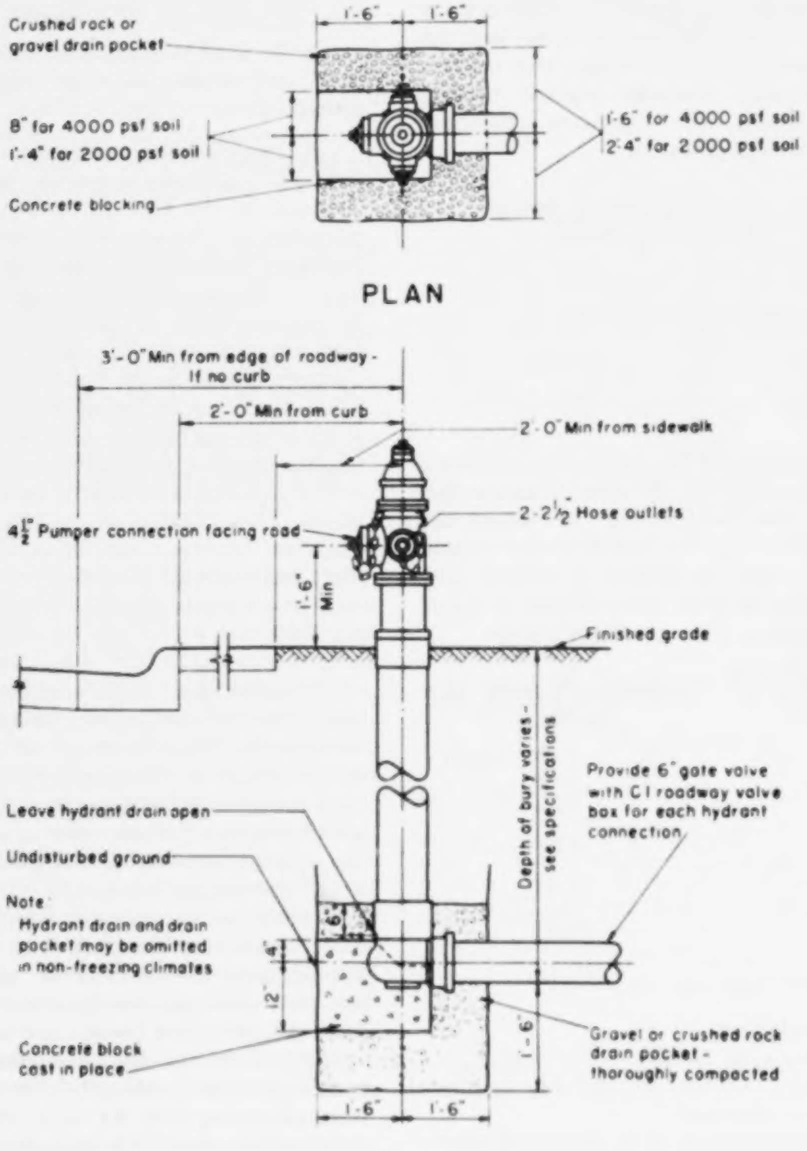
TESTS AND TESTING PROCEDURES

Of course, newly installed pipe has to be tested for leaks by means of air or water. To make an AIR TEST, plug up all openings in the system, connect a source of compressed air to the system, and bring the pressure up slowly to the designed working pressure. Use a soapy water solution and cover each joint, then check for leaks. When a leak is present, you can detect the location by bubbles forming around the joint from the escaping air. When a leak is discovered, mark each spot with chalk or soapstone. **DO NOT, AT THIS TIME, ATTEMPT TO REPAIR THE LEAK.** After the line has been tested completely, relieve the pressure from within and repair the joint. Repeat the testing and repairing procedures until all the leaks have been located and repaired.

The procedure for making a WATER TEST is similar to that used for an air test. Water is used instead of air, and you do not use a soapy water solution to cover the joints. The pipe is filled with potable water, and pressure is applied and maintained by means of a hand pump. See that no air has been retained in the pipe being tested. Let it stand under operating pressure from 4 to 8 hours and inspect for leaks and maintenance of pressure during this period.

DISINFECTION OF WATER-SUPPLY SYSTEM COMPONENTS

Water mains, wells, filters, storage tanks, and other components of a water-supply system become contaminated during installation and repair. Flushing the system to remove dirt, waste, and surface water is the first step in disinfecting


1'-6"
1'-6"
Crushed rock or gravel drain pocket
8" for 4000 psf soil
1'-4" for 2000 psf soil
Concrete blocking
1'-6" for 4000 psf soil
2'-4" for 2000 psf soil
PLAN
3'-0" Min from edge of roadway - If no curb
2'-0" Min from curb
2'-0" Min from sidewalk
2-2½" Hose outlets
4½" Pumper connection facing road
1'-6" Min
Finished grade
Depth of bury varies - see specifications
Provide 6" gate valve with C I roadway valve box for each hydrant connection
Leave hydrant drain open
Undisturbed ground
Note: Hydrant drain and drain pocket may be omitted in non-freezing climates
6"
4"
12"
1'-6"
Concrete block cast in place
Gravel or crushed rock drain pocket - thoroughly compacted
1'-6"
1'-6"
SECTION

54.467

Figure 3-81.—Fire hydrant installation.

the water system, but it is not a sufficient safeguard. To ensure a safe water supply, you must thoroughly disinfect each unit of the system before it is placed in operation. The chemicals used in disinfecting a water-supply system are the same as those used in disinfecting water; for example, a hypochlorite solution or chlorine gas.

Dosage Required

The chlorine dosage required to disinfect any unit depends upon the contact time and the amount of jute, untarred hemp, and organic chlorine-consuming material present. Under average conditions, the following minimum dosages are recommended:

Unit	Minimum dosage (ppm)
Pipe	50
Storage tank	50
Filter	100
Well	150

The volume of water in the unit to be disinfected must be computed before the chlorine dosage can be estimated. Use the formula for finding the volume of a tank ($V = r^2h$) and divide the volume by 231 to determine the number of gallons (231 cubic inches = 1 gallon). The volumes of water in different sizes of pipe are listed below.

Pipe diameter (inches)	Volume per foot of pipe (gallons)
6	1.47
8	2.61
10	4.08
12	5.88
16	10.45
20	16.32

Applying Disinfectant

The following methods of applying disinfectants should be observed:

- Liquid chlorine is applied by portable gas chlorinators. Chlorine cylinders should not be connected directly to mains because water may enter the cylinder and cause severe corrosion and hazardous leakage.
- Hypochlorite solution is usually applied by measuring pumps, gravity-feed mechanism, or portable pipe disinfecting units.

When applying disinfectants, use the following procedures:

- Before adding disinfectant, flush the section thoroughly with water until all dirt and mud are removed. A velocity of at least 3 feet per second is required for adequate scouring.
- Stop all branches and other openings with plugs or heads properly braced to prevent blowouts.
- Disinfect the water mains in sections and feed the disinfecting agent through taps or hydrants at the ends of each section. When a portable gas chlorinator or hypochlorinator is available, feed the discharge from the chlorinator into an auxiliary waterline leading to one of the hydrants or taps. Bleed the air from the line at high points and crowns. Add the predetermined chlorine dosage as the main is slowly filled with water. Continue feeding until the water discharged at the other end of the section contains the desired residual chlorine. Let the chlorinated water remain in the contaminated unit or section for 24 to 48 hours. Then, flush until the chlorine residual is only that amount normally in the supply. Make daily bacteriological analyses of water samples until the analyses show no further disinfection is required.

If a chlorinator is not available, feed a strong hypochlorite solution into the main from a pail through the highest hydrant top or valve with the bonnet removed. Add the hypochlorite and water until the main is full and the chlorine residual is about 50 ppm. Test the residual at the far end of the main. Bleed out air trapped in the line.

If the mains are to be disinfected under pressure by using supply or booster pumps, feed the chlorine into the main with chlorinators or hypochlorite feeders. Take care to ensure adequate and accurate distribution of the disinfecting agent when pumps are being used.

The use of dry calcium hypochlorite directly in mains is not uniformly effective because of unequal mixing with the water. Therefore, when calcium hypochlorite is used, prepare a solution of this chemical beforehand.

Emergencies

Natural contamination of water supplies can increase markedly because of emergencies.

Standby or portable chlorinators must be working to meet emergency disinfection requirements in water-supply components. This equipment cannot be expected to make drinking water safe after bombing, sabotage, or biological warfare make it useless to disinfect with chlorine.

BACKFILLING

When ready to backfill a ditch, tamp the soil around the pipe by hand or use water. In backfilling, keep the pipe straight and minimize settlement. Soil used to backfill around the pipe should be as free as possible from rocks and debris. If you throw fill material directly on the exposed pipe, you could damage the pipe or move it out of alignment. **DROP THE FILL MATERIAL ON BOTH SIDES OF THE PIPE AT THE SAME TIME.**

When you have water available, use it instead of the tamper, especially when you have a short run to backfill. Fill the ditch completely with loose soil. Attach a piece of pipe to a water hose and push it through the loosely replaced soil until it touches the water main. Turn on the water and let it run until the water appears on the surface. This method allows all the earth to be replaced except the volume equal to that of the pipe.

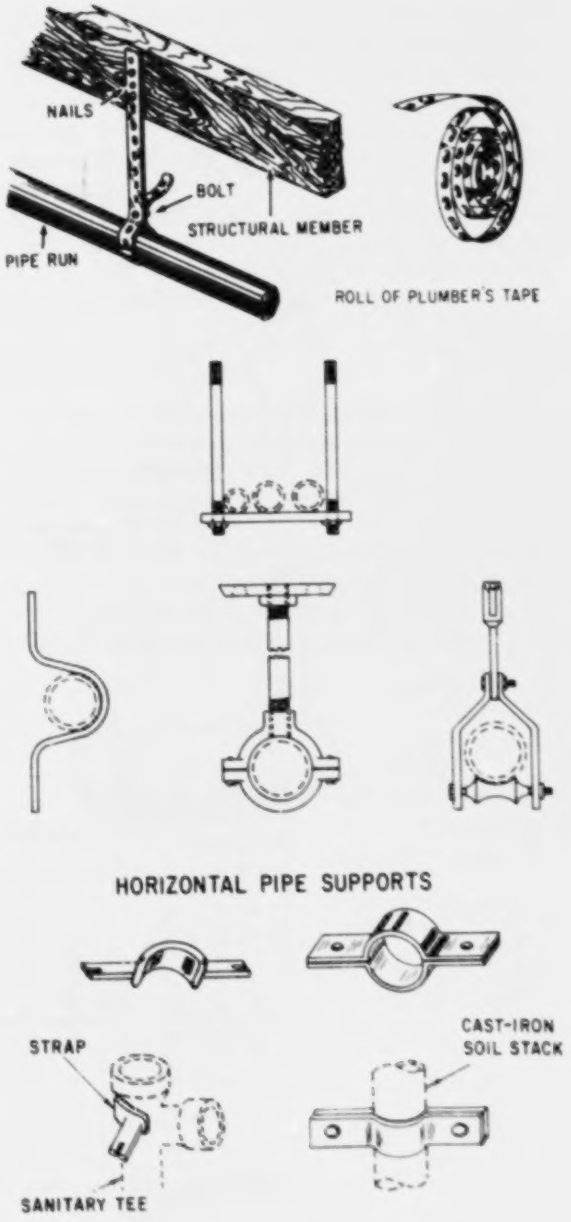
PIPE SUPPORTS

Where pipes are exposed aboveground and in the interior of buildings supplying air, water, or steam, they must be supported adequately to prevent sagging. This is because the weight of the pipes, plus the fluid in them, can cause breaks, strain joints, distort, and cause leaks in valves.

The main supply pipe (vertical or horizontal) must be adequately supported to take its weight off the fitting and to prevent future leaks. Refer to figure 3-82 for some methods of supporting cast-iron soil pipe and galvanized pipe.

Fixture supply risers are pipes taken off of the supply pipes to furnish air, water, or steam to the fixtures being installed. These risers may be in the wall or exposed. They must be made tight and tested before being closed up in a wall. All vertical fixture risers should be supported at each floor level or in a change of direction. They should never be supported by the horizontal fixture supply branches.

As shown in figure 3-82, thrust blocks should be installed on water mains at all changes of direction to prevent pipe from separating from water pressure. Consult the chart at the bottom of the figure for dimensions of thrust block according to pipe size and compaction rating of soil.

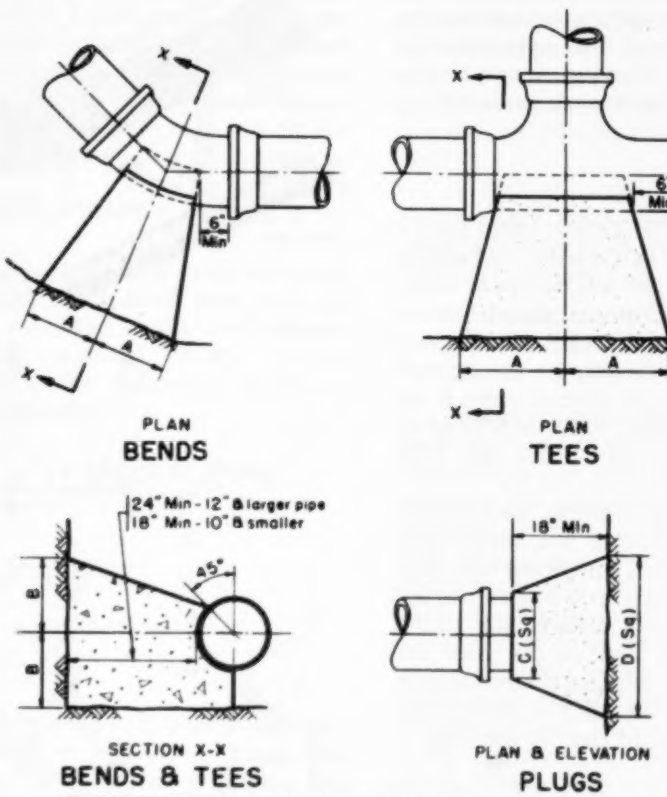


54.57

Figure 3-82.—Methods of supporting pipe.

INSULATION AND MATERIALS

The primary purpose of insulation is to prevent heat passage from steam or hot-water pipelines to the surrounding air, or from the surrounding air to cold-water pipes. Thus, hot


X
6" Min
A
A
X
PLAN
BENDS
X
6" Min
A
A
X
PLAN
TEES
24" Min - 12" & larger pipe
18" Min - 10" & smaller
45°
B
B
SECTION X-X
BENDS & TEES
18" Min
C (Sq)
D (Sq)
PLAN & ELEVATION
PLUGS

TYPE	SIZE	1/4 BENDS		1/8 BENDS		1/16 BENDS		TEES		PLUGS	
		A	B	A	B	A	B	A	B	C	D
TYPE I 4000 PSF SOIL	6"	8"	10"	6"	8"	3"	8"	8"	8"	10"	15"
	8"	12"	12"	8"	10"	5"	9"	9"	12"	12"	20"
	10"	16"	14"	10"	12"	6"	10"	11"	14"	14"	25"
	12"	19"	16"	12"	14"	8"	11"	14"	16"	16"	30"
	14"	23"	18"	14"	16"	10"	12"	16"	18"	18"	34"
	16"	26"	20"	16"	18"	11"	13"	18"	20"	20"	38"
TYPE II 2000 PSF SOIL	6"	16"	10"	9"	10"	6"	8"	10"	12"	10"	21"
	8"	22"	13"	12"	13"	8"	10"	13"	16"	12"	29"
	10"	26"	17"	14"	17"	10"	13"	16"	20"	14"	36"
	12"	29"	21"	16"	21"	11"	16"	18"	24"	16"	41"
	14"	35"	24"	19"	24"	12"	20"	22"	27"	18"	48"
	16"	38"	27"	21"	27"	12"	24"	24"	30"	20"	54"

NOTE: Based on 100 p.s.i. static pressure plus A.W.W.A. water hammer
All bearing surfaces to be carried to undisturbed ground

STANDARD THRUST BLOCKS
FOR WATER MAINS

54.57

Figure 3-82.—Methods of supporting pipe—Continued.

waterlines are insulated to prevent loss of heat from the hot water, while drinking waterlines are insulated to prevent absorption of heat in drinking water.

Insulation keeps moisture from condensing on the outside of cold pipes. An example of condensation consists of droplets of moisture on the outside of a glass of ice water on a warm day. The same thing happens to the outside of a pipe containing cold water when the outside of the pipe is exposed to warm air. Insulation also prevents water from freezing in a pipe, especially when the pipe runs outside a building or in a building without heat.

Insulation is used on heating and air-conditioning ducts. The two kinds of duct insulation are (1) inside and (2) outside. The outside insulation is for the protection of heat loss, whereas the inside insulation is used for protection against noise and vibration from heating or air-conditioning equipment.

Insulation subdues noise made by the flow of water inside pipes, such as water closet discharges. Bathrooms directly above living rooms should be insulated. Insulation is vital in high buildings where water falls a long way, especially if the water falls in soil stacks and headers. Insulation also protects refrigerated and chilled waterlines that cool electrical and motor-driven equipment.

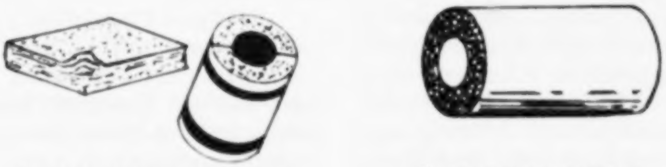
Insulation is made in two forms: rigid preformed sections and blankets. Rigid preformed sections are used on pipe runs and to protect other objects which they are designed to fit. Blanket-type insulation, manufactured in strips, sheets, and blocks, is wrapped around objects that are irregular in shape and large, flat areas. Blanket-type insulation protects against heat loss and fire. This type of insulation is used on boilers, furnaces, tanks, drums, driers, ovens, flanges, and valves. It comes in wool-felt and hair-felt rolls, aluminum foil rolls, and in an irregular preformed covering.

Blanket insulation comes in different widths and thicknesses, depending upon the type of equipment to be insulated. It resists vermin, rodents, and acid. It is also fireproof.

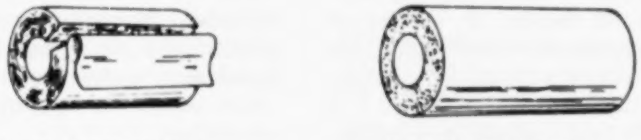
Pipe

Some of the insulating materials on the market today for insulating pipe are sponge felt paper, cork pipe covering, wool felt, flex rubber, fiber glass, magnesia, and types called *antisweat* and *frostproof*.

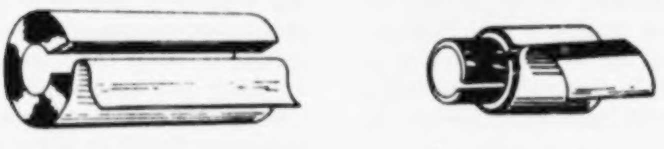
Sponge felt paper is composed of asbestos paper with a maximum amount of sponge evenly distributed within it, as shown in view A, figure 3-83. Sponge felt paper is manufactured to fit


A. SPONGE FELT PAPER INSULATION

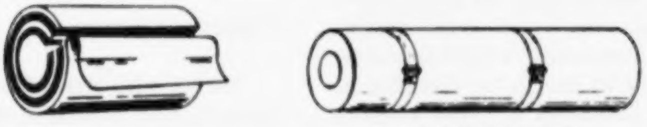
B. MOLDED CORK PIPE COVERING


C. WOOL FELT PIPE COVERING

D. FLEX RUBBER INSULATION


E. FIBER GLASS INSULATION

F. ANTISWEAT INSULATION


G. FROSTPROOF INSULATION

H. PIPE INSULATION SHOWING METAL STRAPS

54.468

Figure 3-83.—Types of pipe insulation.

most pipe sizes. It comes in 3-foot lengths and from 1 to 3 inches in thickness. Sponge felt paper can be purchased in blocks of straight and preformed shapes for valves and fittings.

Cork pipe covering is a granulated material processed from the bark of cork trees. Granulated cork is compressed and molded to size and shape and finished with a coating of plastic asphalt. Cork pipe covering, as shown in view B, figure 3-83, is an ideal covering for brine, ammonia, ice water, and all kinds of cold waterlines, and it insulates well over a wide low-temperature range. Cork pipe covering does not rot or support combustion. Clean, sanitary, and odor free, it is available in a wide variety of sizes and shapes to fit various sizes of pipes and fittings.

Wool felt is made of matted fibers of wool, wool and fur, or hair, worked into a compacted material by pressure rolling. It is used on cold-water service and hot-water return lines. Wool felt preformed pipe covering is manufactured in thicknesses of 1/2 to 1 inch, with a canvas jacket, as shown in view C, figure 3-83. It is manufactured in 3-foot lengths for straight runs of pipe.

Flex rubber insulation, shown in view D, figure 3-83, is a tough, flexible rubber material constructed of millions of uniform closed cells. It has good-insulating qualities, good-cementing qualities, excellent weather-aging qualities, and it is ideal for the prevention of sweating cold waterlines. In addition, it is water and flame resistant. Flex rubber insulation is recommended for covering tubing used in refrigeration and cold waterlines in homes, as well as in industrial plants and commercial buildings. This rubber insulating material comes in random lengths, with a wall thickness size of 3/8 to 3/4 inch. It is made to fit pipe sizes up to 4 inches.

Flex rubber insulation can be installed on pipes and tubing by slipping the insulation over the pipe when it is being assembled or by slitting the rubber lengthwise and sealing it with cement. Before installing flex rubber insulation on iron or galvanized pipes, paint the pipes with an asphaltic base primer to prevent corrosion caused by condensation.

Fiber glass pipe insulation, shown in view E, figure 3-83, is composed of very fine glass fibers, bound and formed together by an inactive resin-type of mixture. It is formed into a flexible hollow cylinder and slit along its length for applying to pipes or tubing. It is furnished in 3-foot lengths, with or without jackets. The insulation comes in thicknesses from 1/2 to 2 inches and fits pipes from 1/2 to 30 inches. Fiber glass insulation has a long life; it will not shrink, swell, rot, or burn. It is easily applied, light in weight, saves space, and has excellent insulating qualities.

Antisweat insulation, shown in view F, figure 3-83, is designed for cold-water pipes. It keeps the water colder in the pipes than most types of insulation; and if properly installed, it prevents condensation, or sweating of the pipes.

The outstanding feature of antisweat insulation is its construction. It is composed of an inner layer of asphalt-saturated asbestos paper, a 1/2-inch layer of wool felt, two layers of asphalt-saturated asbestos felt, another 1/2-inch layer of pure wool felt, and an outer layer of deadening felts with asphalt-saturated felts. The outer layer has a flap about 3 inches long that extends beyond the joint to help make a perfect seal. A canvas jacket is placed around each 3-foot length to protect the outer felt covering.

Frostproof insulation, shown in view G, figure 3-83, is manufactured for use on (1) cold-water service lines that pass through unheated areas and (2) those lines exposed to outside weather conditions.

Frostproof insulation is generally constructed of five layers of felt. There are three layers of pure wool felt and two layers of asphalt-saturated asbestos felt. Frostproof insulation is 1 1/4 inches thick and comes in 3-foot lengths with a canvas cover.

The pipe coverings shown in this section are some of the types of coverings that are easily installed. Primarily because each section is split in half and has a canvas cover with a flap for quick sealing. Joint collars are furnished to cover joint seams on insulation exposed to outside conditions.

Cheesecloth is used on some types of insulation instead of canvas. To install the cheesecloth, use a paste to hold it in place. Allow enough cheesecloth to extend over the end of each 3-foot section to cover the joints.

After you have applied the cheesecloth and smoothed it out, install metal straps to hold the insulation firmly in place, as shown in view H, figure 3-83.

Valves and Fittings

Cover with wool felt, magnesia cement, or mineral wool cement of the same thickness as the pipe covering. These materials are molded into shape to conform with the rest of the insulation. When magnesia or mineral wool cement insulation is used, cover the insulation with cheesecloth to help bind and hold it in place.

Boilers and Storage Tanks

If they are unjacketed, cover them with an approved insulation. Use only insulation approved by the MIL-STD. Some of the approved types of insulation for boilers and tanks are magnesia, mineral wool, calcium silicate, cellular glass, or other approved mineral insulation at least 2 inches thick. Insulation may be of either the block or the blanket type and must be securely wired in place in an approved manner. When applying insulation to the outside of a boiler or storage tank, put it over 1 1/2-inch wire mesh. The mesh is held away from the metal surface by metal spacers that provide an air space of at least 1 inch. When you use blanket- or block-type material, fill the joints in the insulation with magnesia, mineral wool, or other suitable cement. Cover the surface of the insulation with a thin layer of hard-finished cement, troweled smooth, and reinforced with 1 1/2-inch wire mesh.

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CHAPTER 4

PLUMBING REPAIRS

Learning Objective: Recognize methods of identifying problems and performing repairs on water and sewage systems and fixtures, while observing appropriate safety precautions.

Fixing leaky faucets, unstopping clogged sewer lines and fixtures, replacing defective float balls in flush tanks, and thawing frozen pipes are only a few of the jobs that a Utilitiesman may have in plumbing. Even in the best of plumbing systems, failures can be expected from time to time. This is not surprising in view of the use made of faucets, showers, and water closets. When a failure occurs in the plumbing system, you must locate the source of trouble and make the necessary repair or adjustment promptly.

In this chapter, you are introduced to various duties you may have to perform from time to time to keep the plumbing system of your activity in efficient operation. Use the information given here as a foundation on which to build a wider and broader knowledge of the maintenance and repair phase of the plumbing trade. Remember, proper maintenance and upkeep of a plumbing system save dollars by extending the useful life of the fixtures and by conserving water and utilities. Also, porcelain-enameled steel surfaces can, by proper care, be made to last 15 or more years. When proper treatment is given, the period of efficient use of metal faucets, traps, piping, and other fittings may be doubled. Good maintenance of faucets eliminates dripping and saves water. For example, one water faucet, leaking one drop each second, wastes about 2,300 gallons of water a year.

BREAKS IN A WATER SYSTEM

A break in the water distribution system calls for emergency action. To repair a break in the system in the least time, you need trained people and enough material at the job. Here are some real problems when a system breaks down.

- The water supply generally available for fire protection is seriously reduced or does not exist.
- Escaping water under pressure seriously undermines the structure, damages foundations, destroys landscaping, or causes erosion.
- While the pipe is broken, a health hazard exists because the distribution system can be contaminated by external sources.
- The water supply for normal domestic or industrial use can be completely cut off.

To ensure proper maintenance of a water distribution system, keep charts and maps on hand showing existing conditions in all parts of the system. At some activities, records may not be available showing the exact location of important buried lines. In such instances, learn their exact location and record any changes on a master chart or map. Maps of the entire water system should be available, showing the following locations:

- Sources of supply. If a surface supply, the sizes of intakes, cribs, dams, and impounding reservoirs should also be shown.
- Wells, pumping stations, and treatment plants.
- Storage reservoirs and elevated tanks with capacities indicated.
- All mains, valves, hydrants, and relief valves with sizes indicated.
- Service lines with sizes and point of entrance to buildings.

At some activities, electronic devices are available for subsurface survey and pipe location work. Sometimes you may have to find points of interconnection, pipe diameters, and the condition of exterior surfaces or coatings. For future use, make notes on the maintenance maps or charts to show the general condition of the system. Use a symbol that stands out to show the approximate age of the installation or its parts. Charts and maps should be complete and up-to-date. In maintenance or repair, these charts or maps help in planning maintenance. Many times, they offer clues to the most probable location and probable cause of trouble.

Now and then the system should be flushed through hydrants and blowoffs to remove scale and accumulation in pipes and fittings. When performing this operation, start at the hydrants or blowoffs nearest the source of supply to conserve water and to stir up less of the distribution system. Each point should be flushed until the water comes out reasonably clear. All valves should be in their normal operating positions before you go on to the next point.

Flushing dead ends is vital. When flushing does not induce enough velocity to scour the mains clean, night flush them with a large discharge. Night operation lessens work disruption caused by water shutoff and by decreased water pressure.

WATER MAINS

Since water main breaks must be repaired as fast as possible, personnel must be trained and repair plans made in advance. The following procedures are essential:

1. Post the telephone numbers of the fire department and key personnel and have alternate personnel available in case members of the regular repair crew cannot be reached at the time of a break. Notify the public works officer at the time the break is reported.
2. Always keep the following items readily available: valve keys, hand tools, digging tools, pavement breakers, trench shoring, a portable centrifugal or diaphragm pump, floodlights, an emergency chlorinator, and calcium hypochlorite powder.
3. Maintain enough pipe repair materials and supplies.

As a temporary measure, wooden plugs can be used to stop small holes in a main. These plugs can be replaced later with metal plugs, or repairs may be made by other means. Wooden plugs can also be used temporarily to plug the ends of a pipe up to 8 inches in diameter, but such plugs must be braced to withstand existing main pressure.

After repairs are completed, the main must be disinfected. You probably recall that disinfection was discussed earlier in chapter 3 of this training manual.

THAWING FROZEN PIPES

In cold weather, a water-supply system can freeze. Because of the lack of protection against freezing, and sometimes regardless of it, pipes frequently freeze in temperate zones. When this happens, the pipes must be thawed. Breaks must be found, if possible, before natural thawing to prevent damage to material and property. Alert personnel to watch for the signs of a broken line. The prevention of freezing pipes can sometimes be accomplished by using heat tapes and cables.

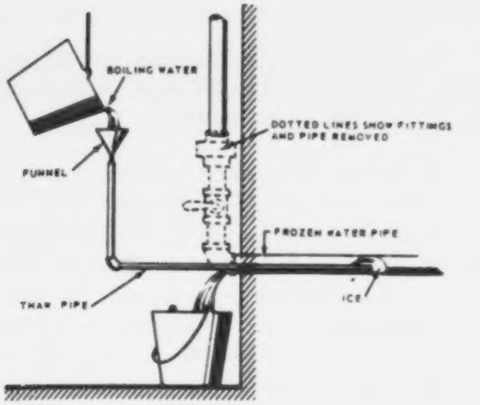
Before starting to thaw a frozen pipe, open faucets affected by the freeze. Frozen pipes can be thawed by applying heat at the lowest open end of the frozen section. (Do NOT start in the middle of a frozen section because a pocket of steam could develop and an explosion or damage to the pipe can occur.) Where there is no danger of fire, simply heat the pipe with a blowtorch, applying the flame on the outside of the pipe.

When thawing frozen water pipes or heating pipes inside of buildings, use hot water. Do NOT use an open flame. A safe method is to wrap the frozen section of pipe with cloth and pour hot water on it until the ice gives way. Remember to protect the floor by catching the water in buckets or by covering the floor with material to absorb the water.

A good method of thawing water pipes that are underground or otherwise hard to get to is shown in figure 4-1. When using this method, remove the fittings (see illustration) and insert one end of the small pipe or tube into the frozen pipe. Now add an elbow and a piece of vertical pipe to the outer end of the thaw pipe. Place a bucket under the opening to the frozen pipe and insert a funnel in the open end of the vertical pipe. With that done, start pouring boiling water through the funnel into the pipe. As the ice melts, push the thawed pipe forward. Where necessary, add pipe at the outer end until a passage is made through the ice.

Withdraw the thaw pipe quickly after the flow starts and do not stop the flow until the thaw pipe is fully removed and the pipe cleared of ice.

Instead of a funnel, a small force pump can be used. This pump is useful for thawing a long

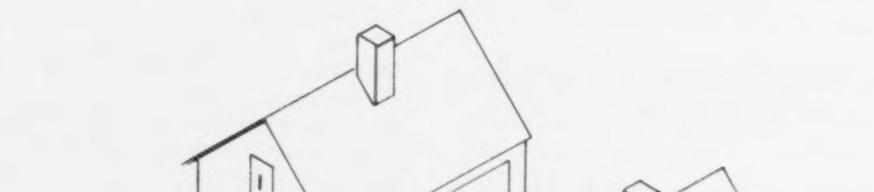

BOILING WATER
DOTTED LINES SHOW FITTINGS AND PIPE REMOVED
FUNNEL
FROZEN WATER PIPE
THAW PIPE
ICE

54.72
Figure 4-1.—Thawing an underground or otherwise inaccessible pipe.

piece of pipe. When available, you can use steam in place of hot water. The above method can also be used without the elbow and piece of vertical pipe shown in figure 4-1. Simply connect the funnel to the outer end of the thaw pipe with rubber tubing. Have the tubing long enough so you can hold the funnel above the level of the frozen pipe. In this way, you give the hot water a head, forcing the cooled water back to the opening where it runs out into the pail. Hence the advantage of the elbow and vertical pipe is that they increase the head of the water and make the use of the funnel easier.

ELECTRICAL THAWING

Electrical thawing of frozen service lines is quick and cheap. The electrical current for the thawing operation consists of a source of current (a dc generator, such as a welding outfit, or a transformer connected to an ac outlet) and two insulated wires connecting the current source and the pipe (fig. 4-2). Only qualified personnel should


1
2
B
F
A
SERVICE LINE
SIDEWALK
E, VALVE BOX
WIRE
B'
F'
A'
G, MAIN
C, HYDRANT
SERVICE LINE
D
ELECTRICAL WELDING UNIT
THIS WIRE CONNECTED TO: A', F', C, D, E, OR G

54.209
Figure 4-2.—Connection points for thawing frozen service lines.

use power lines as a source of current. As current flows through the pipe, heat is generated, and the ice within the pipe begins to melt. As the water starts to flow, the rest of the ice is melted by contact with the flowing water. The wires from the current source may be connected to nearby hydrants, valves, or exposed points at the ends of the frozen sections. Some data on current and voltage required for electrical thawing of various sizes of wrought-iron and cast-iron pipes are presented in table 4-1.

The time for electrical thawing may vary from 5 minutes to over 2 hours, depending on pipe size and length, intensity of freezing, and other factors. The best practice is to apply current until the water flows freely.

Precautions

Some precautions in electrical thawing are given below.

- Avoid higher current than listed in table 4-1. When in doubt, use low current for a longer period.

- Select contact points on the pipe as close as possible to the frozen section.

Table 4-1.—Relation of Current and Voltage Required for Thawing

Type of pipe	Pipe size (in.)	Pipe length (ft.)	Approximate (volts)	Approximate (amps.)[1]
Wrought Iron	3/4	600	60	250
	1	600	60	300
	1 1/2	600	60	350
	2	500	55	400
	3	400	40	450
Cast Iron	4	400	50	500
	6	400	50	600
	8	300	40	600

[1] USE NO MORE THAN 100 AMPERES ON LEAD PIPES WHICH HAVE LEAD FITTINGS OR ANY SOLDERED JOINTS.

- Assure that contact points are free of rust, grease, or scale.

- Remove meters, electrical ground connections, and couplings to buildings with plumbing in the pipeline to be thawed.

- If there are gaskets or other insulation at pipe joints, thaw the pipe in sections between such joints, or use copper jumpers to close the circuit across insulated points.

Procedures

Use the following procedures in electrical thawing:

1. DIRECT-CURRENT GENERATOR. To thaw pipes with a welding generator or similar direct-current source, set the generator to the correct amperage for the pipe to be thawed and connect the leads to the pipe.
2. ALTERNATING-CURRENT CIRCUIT. Transformers are required to adjust amperage of an alternating-current circuit to the pipe being thawed. To reduce hazards, have a competent Construction Electrician set and connect transformers, make the connections, and assist in the thawing process. Where frequent thawing is necessary at different points, the transformers may be mounted on a trailer for ready use.

STEAM THAWING

Steam thawing of frozen systems is slower than electrical thawing and should be used only when insulating materials in pipes (plastic, transite, wood), pipe joints, or couplings make the use of electricity impractical. In steam thawing, a hose connected to a boiler is inserted through a disconnected fitting and gradually advanced as the steam melts the ice.

VARIATION OF WATER PRESSURE

A change of water pressure can cause much discomfort to persons using the plumbing system. The mixture of hot and cold water from a shower can suddenly vary in temperature or rate of flow when water is turned on at another outlet. Failure to remedy this condition could injure somebody, especially if the temperature is scalding.

When a switch in pressure and water flow occurs often, look in the water pipes. Check the pipes to see if they are of the proper size in diameter for their length and height as originally installed. Also look for liming and corrosion inside the pipes. Enough liming and corrosion can reduce the diameter of the pipe, causing low pressure and slow water flow.

Sometimes the trouble occurs after more fixtures have been installed in the system. When this happens, the piping is probably overloaded because of the extra fixtures. Pressure and water flow may also change when there is too much friction in the pipe, too many fittings, and the piping changes in direction.

If the pressure at showers changes only when other outlets are open, you can usually correct the trouble by installing automatic mixing valves. The only answer to an increase in the water flow from pipes that are too small is to replace them with larger pipes.

PIPE LEAKS

When a leak develops at a threaded joint of pipe, one of the most likely suspects is a fractured or ruptured pipe. Fractures often occur at the end of a length of pipe because of strain imposed by vibration of water hammer. It occurs at the end of the pipe because the wall thickness is decreased and weakened by threading. The risk of fracture becomes even greater when the threads are not cut true. In cold climates, freezing sometimes causes pipes to rupture, in which case replacement becomes necessary. A loose or cracked fitting can also cause leakage at the threaded joint of a pipe. These and other common failures resulting in pipe leakage make it important for you to determine the exact location and cause of failure before commencing any repairs to the piping.

LOCATING LEAKS

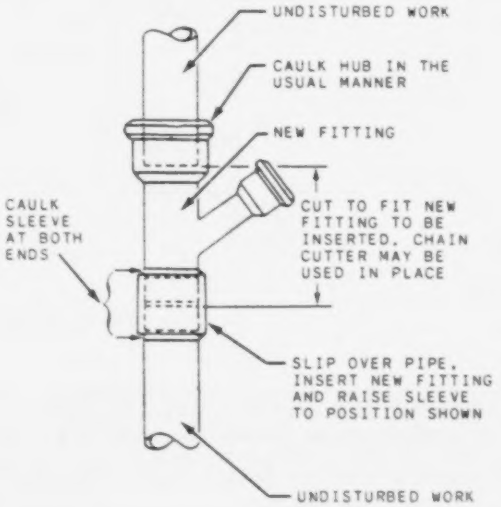
Find and repair leaks in the water piping system as quickly as possible to prevent serious damage to footings, walls, floors, plaster, and other parts of the structure, and to conserve water. Find leaks systematically by inspecting exposed piping and valves and by examining walls, floors, and ceilings around concealed piping. You should also check gauges, meters, and other water flow recording devices for evidence of abnormal flow, which might reveal loss through leakage.

In galvanized pipe installations, where the fittings on either side of the leak are not readily available, the leaking section may be cut out. In this operation, one person holds the pipe with a wrench to keep it from turning in the next fitting, and another person cuts a thread on it—while it is in place—using a hand type of pipe threader. The cutout section is then replaced with a coupling, a pipe section of the required length, and a union.

You may also have to repair leaks in copper piping. If a copper pipe leaks, cut out the damaged section and replace it with a new section, using either soldered or compression-type joints.

When a piece of cast-iron pipe less than full length is needed for replacement, cut it from a double-hub pipe so the remaining piece has a hub left for use in other work.

If you need a fitting for a short space or if existing work cannot be removed easily, use short spigot ends for sleeves. Closely observe figure 4-3. This figure shows how to install a fitting in a restricted space.


UNDISTURBED WORK
CAULK HUB IN THE USUAL MANNER
NEW FITTING
CAULK SLEEVE AT BOTH ENDS
CUT TO FIT NEW FITTING TO BE INSERTED. CHAIN CUTTER MAY BE USED IN PLACE
SLIP OVER PIPE, INSERT NEW FITTING AND RAISE SLEEVE TO POSITION SHOWN
UNDISTURBED WORK

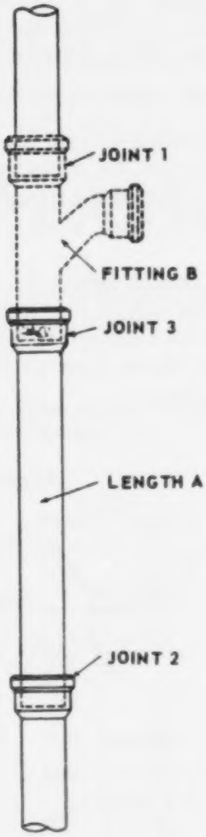
54.73

Figure 4-3.—Installing a fitting in restricted space.

Replace a fitting or insert one into an existing line by following the four-step procedure shown in figure 4-4.

When the job calls for adding connections to an outside vitrified clay sewer line, here is one step-by-step method.

1. Remove a section of the existing sewer pipe that is long enough to receive a new Y-fitting.
2. Break half of the hub rim of the new Y-fitting, as indicated in view A, figure 4-5.
3. Insert the spigot end of the Y-fitting into the hub of the existing pipe. At the same time, place the remaining half of the hub end of the Y-fitting over the cut end of the existing pipe with the Y-branch pointing away from the new inlet. (See the first position of view B, fig. 4-5.)



STEP 1. MELT LEAD FROM JOINTS 1 AND 2.
STEP 2. CUT PIPE A TO CORRECT LENGTH.
STEP 3. ASSEMBLE PIPE A AND FITTING B AND INSERT INTO LINE.
STEP 4. STRAIGHTEN LINE AND CAULK JOINTS 1, 2, AND 3.

54.74

Figure 4-4.—Inserting a fitting in an existing line.

4. Rotate the Y-fitting so the broken half of the hub is up and the Y-branch is in the correct position to receive the new inlet connection. (See the final position of view B, fig. 4-5.)
5. Pour the joint carefully; round over the broken half of the hub with plenty of concrete or mastic compound, as indicated in view C, figure 4-5.

EMERGENCY REPAIR

At times, a pipe may start leaking and the materials needed to repair it permanently are not on hand. Here, you may have to use a temporary or emergency repair. Keep in mind that a permanent repair should always be made when the proper tools or materials are available.

One simple method of making a temporary repair of a leaky pipe is to use a length of rubber hose. After turning off the water supply, remove the defective section of the pipe by cutting it with a hacksaw. Then take a piece of rubber hose, slightly longer than the section of pipe you removed, and slip it over the ends where the cut was made. (See view A, fig. 4-6.) Ensure the inside diameter of the hose matches the outside diameter of the pipe. Hose clamps hold the hose securely in place.

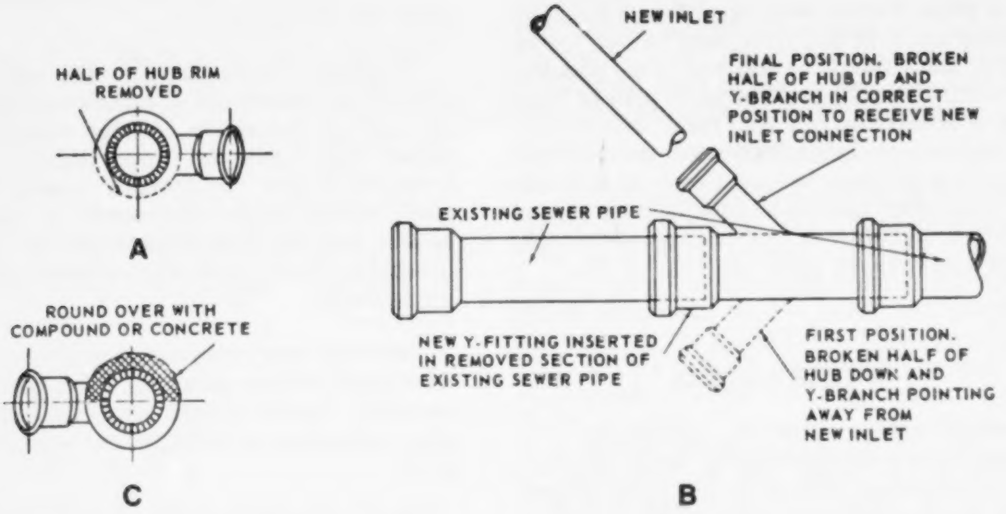
Another temporary method of repair for a leaky pipe is to wrap the leaky area with sheet rubber. Then place two sheet metal clamps, one on each side of the pipe, on the sheet rubber covering, as indicated in view B, figure 4-6. Now, fasten the clamps with bolts and nuts.

NOTE: Sheet metal clamps for this type of repair can be made from scrap material from the sheet metal shop. You may want to make up a few of these clamps to keep on hand for an emergency repair job.

You can also secure the water supply, drain the water from the pipe, clean the pipe surfaces thoroughly, apply flux, and then wrap clean copper wire over the rupture and solder.

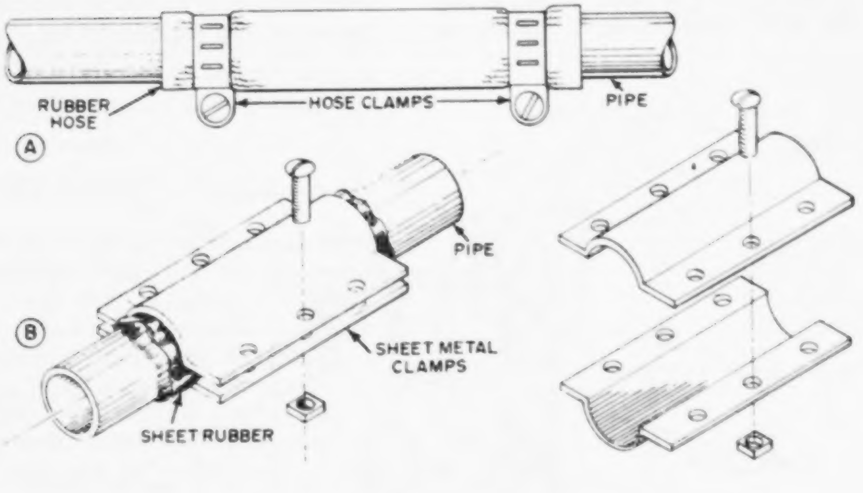
WATER TANK FAILURES

Where a plumbing system has been in use for some time, two failures in water tanks are (1) leaky seams and (2) corroded areas requiring


NEW INLET
HALF OF HUB RIM REMOVED
FINAL POSITION. BROKEN HALF OF HUB UP AND Y-BRANCH IN CORRECT POSITION TO RECEIVE NEW INLET CONNECTION
EXISTING SEWER PIPE
A
ROUND OVER WITH COMPOUND OR CONCRETE
NEW Y-FITTING INSERTED IN REMOVED SECTION OF EXISTING SEWER PIPE
FIRST POSITION. BROKEN HALF OF HUB DOWN AND Y-BRANCH POINTING AWAY FROM NEW INLET
C
B

54.75

Figure 4-5.—Adding connections to outside vitrified clay sewer pipe.


RUBBER HOSE
HOSE CLAMPS
PIPE
Ⓐ
PIPE
Ⓑ
SHEET METAL CLAMPS
SHEET RUBBER

54.76

Figure 4-6.—Temporary type of repairs of leaky pipe.

welded patch plates. To repair a defective seam, first drain the water tank dry. Then clean the surfaces to be repaired until they are bright. By welding or brazing, the leaky portions can then be made watertight.

As an effective tank patch for a large hole, you need both a temporary and a permanent patch. One temporary patch is a tapered softwood plug. Insert the plug in the hole, and tap it lightly with a hammer until the seal is watertight. Then saw off the top of the plug so it is flush with the tank wall.

Next, the area around the plug to be covered by the permanent patch should be cleaned by wire brushing. Drain the tank; now you are ready to apply the permanent patch. One type of permanent patch includes a rubber gasket and a metal plate. Rubber sheeting, at least 6 inches by 6 inches and 1/16 inch thick, may be used for the gasket, and it should be centered on the plug and cemented with adhesive. The patch plate of black steel or nonferrous (no iron) metal should be of the same material and thickness as the tank wall but a lot larger than the hole. Cover the hole with the metal plate, keeping an equal overlap around the edges, and braze or weld the plate to the tank, using a continuous seam.

WATER METERS

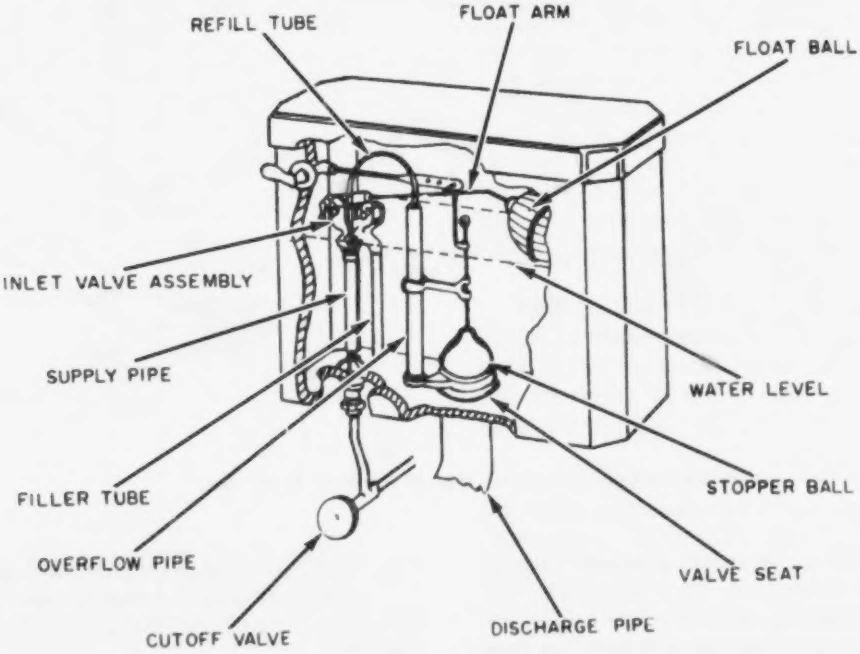
Water meters must be maintained. The schedule for a volume type of meter used as a service meter and for sizes up to 6 inches is listed in the paragraphs below. The frequency of inspection indicated is subject to change by your local command.

Monthly, make certain that the meter is operating properly. If it is noisy, remove and examine the parts, and repair or renew as required. Check the dial face for cleanliness, and clean the glass dial cover.

Annually, make certain that the meter has not been moved out of a horizontal position. In locations subject to freezing temperatures, inspect and clean the meter housing or pit 1 month before the freezing season begins; also, make certain the meter is protected against freezing. Check the meter for damage if water backs up from an improperly installed water heater.

Now and then, clean and inspect the meter for worn parts; change gears and other parts when necessary. Meters should always be calibrated after replacement of worn parts or after changing gears.

Each activity should keep a schedule for cleaning and repairing meters. This schedule is based on experience with meters in the system and the costs of metering. A large volume of water registered in a short time can cause more deterioration of the meter than a small volume registered over a longer period. So, the schedule



54.392

Figure 4-7.—Water closet flush tank.

for cleaning and repairing meters should be similar to this.

Size (in.)	Registration (cu ft)	Service (yr)
5/8		
3/4		
1		
1 1/2		
2		
3		
4		
6		

Disassemble the meter under the manufacturer's instructions. Remove sediment; check the interior for corrosion or wear; replace worn gears; replace the disk or the piston when necessary; clean and brighten the exterior by wire brushing and shotblasting, or by acid dip.

CAUTION: Use acid dip only under the manufacturer's instructions and Naval Facilities Engineering Command safety procedures.

WATER CLOSET BOWLS

Moisture on the floor at the base of a water closet bowl usually means the seal or gasket between the closet and its outlet has failed. However, it can result from condensation on the tank or piping or from leakage of the tank, flush valve, or piping. When the seal leaks, remove the water closet bowl and install a new seal to prevent damage to the building. This also prevents entry of sewer gas into the room.

NOTE: In servicing plumbing fixtures, you have the job of clearing stoppages in water closets. Information on tools and chemicals used in clearing stoppages in water closets and other fixtures is given later in this chapter.

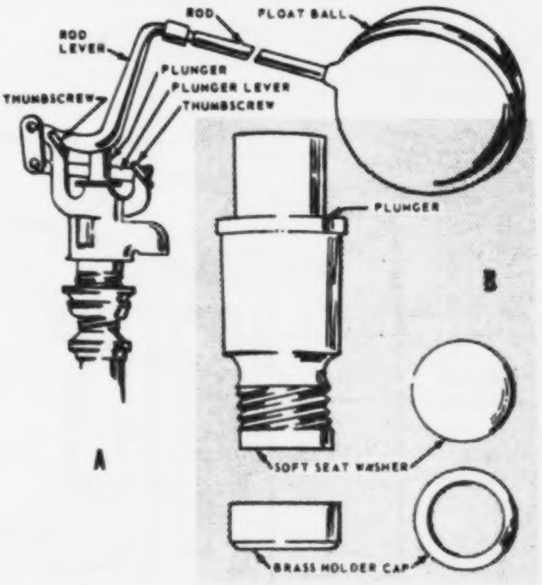
FLUSH TANK

Get to know the basic principle on which flush tanks operate. This will help you find the source of trouble when a tank gets out of order. Before undertaking repairs, you must understand the operation of various components in a flush tank. For clarity, refer to figure 4-7. Keep in mind that in different types of flush tanks you may find some change in the method of operation.

PRINCIPLE OF OPERATION

When you trip the lever outside the flush tank, the rubber STOPPER BALL is raised from the VALVE SEAT to release water into the closet bowl. During this emptying, the FLOAT BALL moves downward as the water level recedes. Movement of the FLOAT ARM causes a plunger in the INLET VALVE ASSEMBLY to open and a new supply of water to be admitted through the SUPPLY PIPE. The stopper ball seats as the water flows from the tank; incoming water helps to hold the ball in place. Hence the new supply of water is held for the next flushing. As the water level rises during refilling, the FLOAT BALL also rises with it. The buoyance of the float ball provides the force needed to lower the plunger (fig. 4-8) to shut off the water as the tank fills.

In figure 4-7, notice that there is a small REFILL TUBE that feeds into the OVERFLOW



54.79

Figure 4-8.—A. Ball cock assembled; B. Plunger, washer, and cap.

PIPE. In refilling, water passes through this tube and into the OVERFLOW PIPE and to the closet water trap. The refill tube ensures replacement of water in the trap. This water must be replaced to keep sewer gases from coming through the waste pipe.

REPAIRS

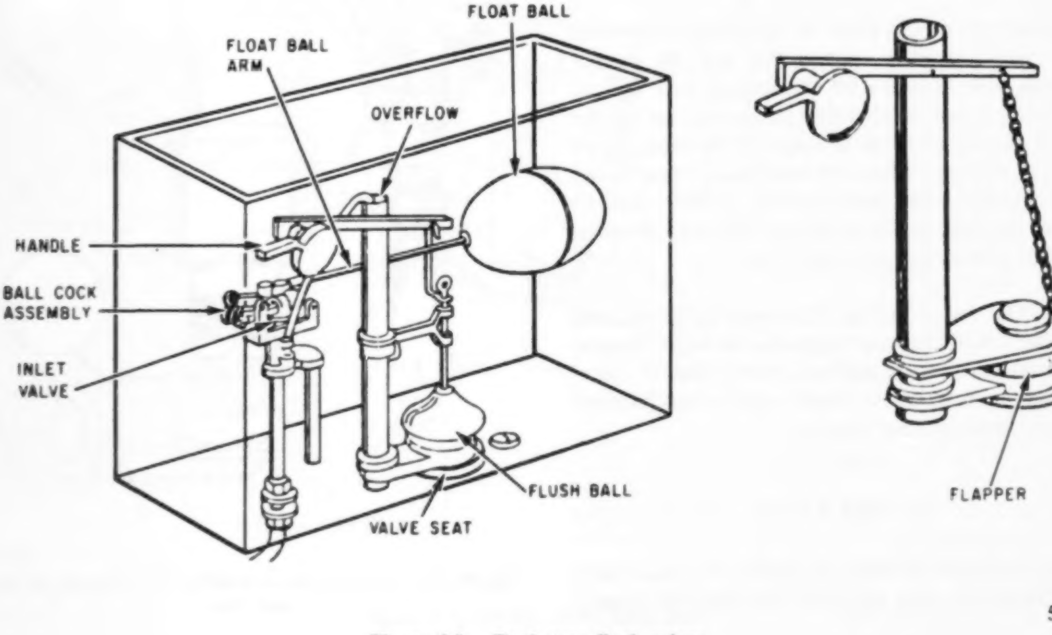
When water continues to run into the closet bowl after the flush tank is full, the trouble is in some part of the inlet valve assembly (ball cock assembly). As you can see—if you understand the details of operation given above—the plunger has failed to close the inlet valve as it should, and thus the excess water that continues to flow in (after the tank has reached the proper level) is being discharged through the overflow pipe and into the bowl. In checking for the source of trouble, several defects to look for are a leak in the float ball, a bent float arm, a worn washer on the bottom of the plunger, or a worn valve seat.

Start with the float ball, keeping in mind that a leaky, waterlogged float prevents the plunger from closing properly. A small leak in a copper float ball can be remedied by soldering. If it is a large leak, though, simply replace the float ball with a new one. A damaged float arm should also be replaced with a new one. Sometimes the float arm is bent or does not allow the valve to close far enough. In this case, bend the float end downward a bit to push the valve tighter into its seat.

To replace the washer on the bottom of the plunger (view B, fig. 4-8), start by shutting off the water. Now, unscrew the two thumbscrews that pivot the float rod lever and the plunger lever (view A, fig. 4-8). Push the two levers to the left, drawing the plunger lever through the head of the plunger. Now, lift out the plunger, unscrew the cap on the bottom, insert the new washer, and reassemble the parts. If the cap is badly corroded, replace it with a new one. When replacing the washer, examine the seat for nicks and grit. The seat may need regrinding.

Suppose water continues to run into the closet bowl after flushing, yet the tank does not refill. Some part of the FLUSH VALVE assembly is at fault because the flush valve is not closing properly. To locate the trouble and get the tank back in order, proceed as follows:

First, stop the inflow to the tank by holding up the float ball or supporting it with a stick. Then drain the tank by raising the rubber stopper ball or the flapper. (See fig. 4-9.) Now, examine the stopper ball to see if it is worn, out of shape, or has lost its elasticity. If either condition exists, unscrew the lower lift wire from the ball and replace the ball with a new one; or if it is a



54.496

Figure 4-9.—Tank-type flush valves.

flapper valve, remove the flapper and replace. There are no lift wires or wire guides to adjust on the flapper valve type of flush valve. Ensure the lift wire is easily fitted over the center of the valve by means of the adjustable guide holder. By loosening the thumbscrew, you can raise, lower, or locate the holder over the overflow tube (fig. 4-9). The horizontal position of the guide is fixed exactly over the center of the valve by loosening the locknut and turning the guide screw.

The upper lift wire should loop into the lever armhole directly above the center of the valve. The tank should empty within 10 seconds. Because of lengthening of the rubber ball and insufficient rise from its seat, the time needed to empty the tank may be longer than 10 seconds and the flush weak. In this case, shorten the loop in the upper lift wire. Also, a drop or two of lubricating oil on the lever mechanism makes it work more smoothly.

FLUSHOMETERS

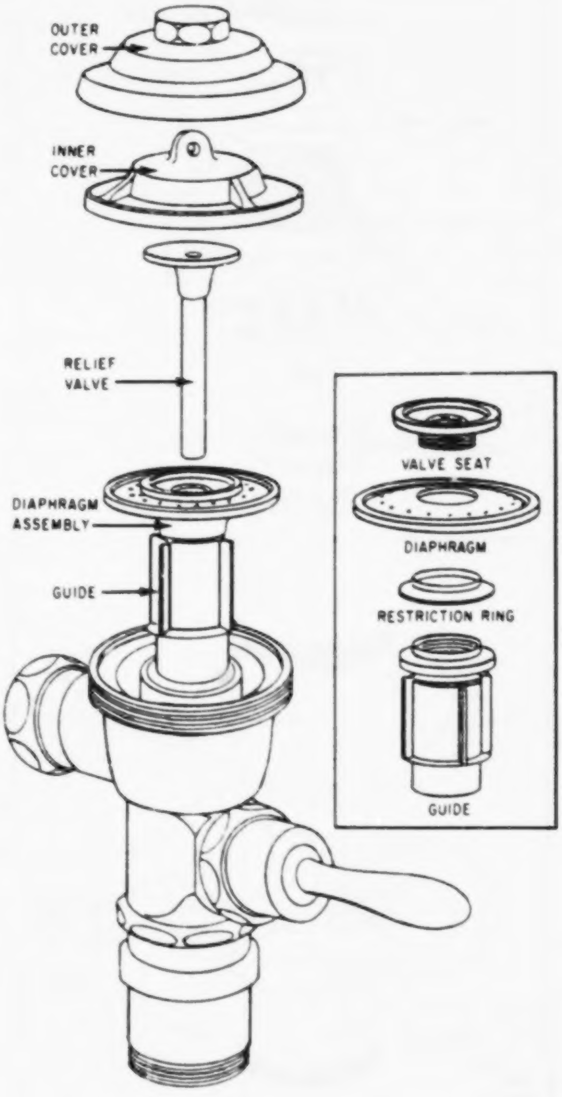
Two major problems with flush valves are (1) the valve may run continuously, instead of shutting off at the right time, or (2) the valve may fail to deliver the desired amount of water (short flushing). Both of these defects can waste much water over a long period of time. Since flush valves are installed to avoid waste, they must be properly maintained. Once you understand the principle and the operation of a valve, you can keep a flushometer in good repair. A flush valve gives years of adequate and trouble-free operation when it is properly installed and maintained.

Continuous flow of water through a piston type of flush valve is almost always caused by failure of the relief valve to set properly or by corrosion of the bypass valve. In both cases, there is not enough force on the piston to force it to seat.

If the relief valve fails to seat as it should, the leakage may be enough to prevent the upper chamber of the valve from filling, and the piston remains in the open position. Inspect the relief valve seat for dirt or other foreign substances that may be causing the relief valve to tilt; disassemble the piston, wash the parts thoroughly, and reassemble. Replace washers that are worn, making sure that the surface upon which the washer sets is perfectly clean; scrape off old rubber if any sticks to the metal surface.

Corrosion of the bypass valve in the center of the top plate also causes continuous flow; the water cannot pass into the upper chamber of the valve, and no force is exerted on the piston to move it downward to its seat. Very dirty water passing through the system can clog the bypass and deprive the upper chamber of water. When pipelines in a new installation are not thoroughly flushed before they are placed in operation, the pipe dope or dirt in them can stop up the bypass valve.

Likewise, in a diaphragm valve (fig. 4-10), if chips or dirt carried by the water lodge between

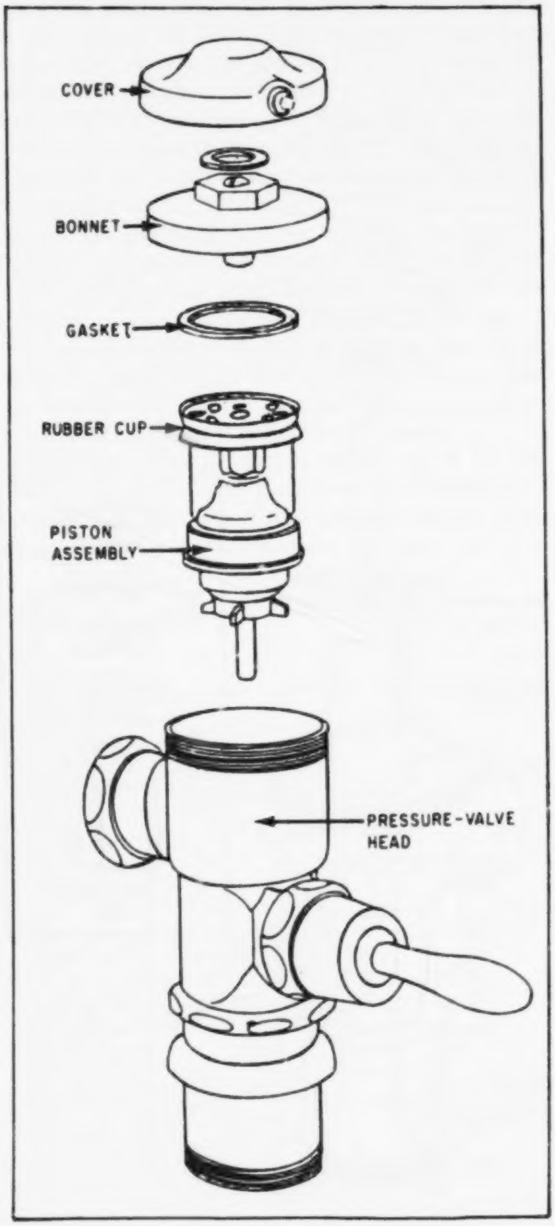


54.497

Figure 4-10.—Diaphragm type of flushometer.

the relief valve and the valve seat, the relief valve cannot seat securely. The water leakage prevents the upper chamber of the valve from filling with water. The valve then remains in the open position, since there is no pressure to force the diaphragm to its seat.

Short flushing can occur in a diaphragm type of valve. If the valve seat, diaphragm, and guide have not been tightly assembled, you should reassemble the valve to ensure proper operation. Sometimes you may find the bypass tube has been tampered with, enlarging it so the water passes rapidly into the upper chamber and closes the valve before the desired volume is delivered. Also, someone may have oiled or greased the valve parts to make the valve operate more easily. What actually happens is the oil or grease swells and ruins the rubber parts, interfering with the action of the valve.



54.498

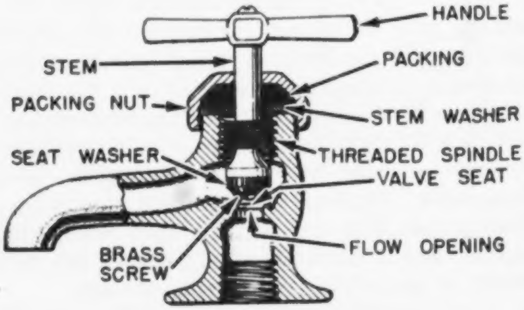
Figure 4-11.—Pressure-valve head flushometer.

Another commonly used unit is the pressure-valve-head flushometer (fig. 4-11). The most common problem with this type of flushometer is the rubber cap. To replace the rubber cap is a simple task; remove the retaining screws, lift out the plate, and remove and replace the cap.

FAUCETS

You may recall from chapter 3 that a number of different types of faucets are used in plumbing installations. Since space is limited, only repairs to the compression type of faucet are presented. If you can repair this faucet, you should have little trouble in repairing other types of faucets. A cutaway view of a compression faucet is shown in figure 4-12. This faucet, with a disk washer and a solid or removable seat, requires frequent attention to maintain tight closure against water pressure.

When a faucet is turned on or off, the washer on the end of the stem rubs against the seat. This rubbing action wears down the washer and eventually causes the faucet to drip. Even a small, steady leak in a faucet, if ignored for long, can waste a lot of water. For economy purposes, a dripping faucet should be fixed promptly. Frequently, the remedy for a dripping faucet is



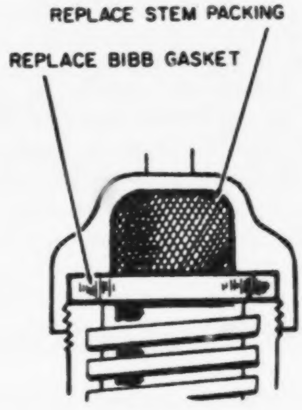
54.81

Figure 4-12.—Compression faucet.

simply to replace the washer. Be sure to replace flat or beveled washers with washers of the same design.

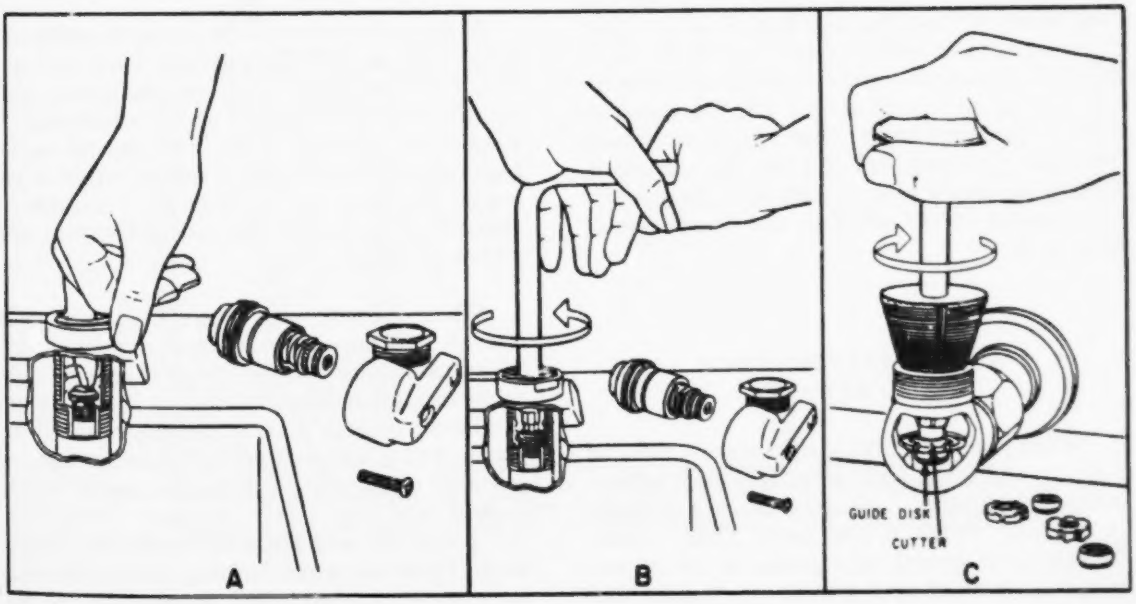
To replace the disk washer on a compression faucet, first shut off the water supply to the faucet and open the faucet all the way. Now, remove the faucet handle, bonnet, and stem. Next, remove the brass screw holding the washer to the bottom of the spindle. Replace the washer with a new one which is flat on one side and slightly rounded on the other, so it can get both horizontal and vertical pressure and provide a firm seat. Use a good quality hard-composition washer because leather or soft washers do not give long service, particularly in hot-water lines. If the brass screw is in poor condition, replace it with a new one. (See view A, fig. 4-13.)

Examine the valve seat and repair or replace it with a new one (view B, fig. 4-13), if necessary, before replacing the spindle; otherwise, a new washer provides adequate service for only a short time. Reface or ream solid seats (view C, fig. 4-13) with a standard reseating tool consisting of a cutter, stem, and handle. Rotate the tool with the cutter centered and held firmly on the worn or scored seat. Take care to prevent excessive reaming. Remove all grinding residue before reassembly. A solid seat can be replaced with a renewable seat by tapping a standard thread into the old solid seat and inserting a renewable seat. Remove renewable seats with a regular seat-removing tool or allen wrench. When the seat is frozen to the body, apply penetrating oil to loosen it. Faucet seats can usually be tapped, reseated, or replaced without removing the faucet from its fixture. To stop leakage at the bonnet, replace the stem packing and the bibb gasket (fig. 4-14).



54.211

Figure 4-14.—Stopping leak at bonnet.



54.499

Figure 4-13.—Inspecting, removing, and refacing faucet seats.

Occasionally, you may find ball-bearing washer holders installed in faucets at some activities. The ball bearings between the stem and washer holder permit movement of the "washer" free of the movement of the stem. This allows the washer to stop its rotation on the slightest contact with the seat, thereby reducing the frictional wear of the washer.

SHOWER HEADS

Shower heads that supply an uneven or distorted stream can usually be repaired by removing the perforated faceplate and cleaning the mineral deposits from the back of the plate with fine sandpaper or steel wool. You can free clogged holes with a coarse needle or with compressed air.

INSULATION AND HANGERS

When insulation is properly installed, it should remain good a long time. However, accidents, such as broken hangers and leaking valves, do occur. To repair a section of bad insulation, you may need just to recover the insulation with waterproof paper or canvas; this depends upon the situation. Before doing repair work to the insulation, try and find the cause of failure; then correct the basic source of trouble. Sometimes a hanger comes unfastened or breaks and causes the pipe to sag and break or to crack. So, repair or replace the pipe hanger. Then repair (or replace) the pipe or fitting and reinstall the insulation. Follow the instructions presented in chapter 3 of this manual on the selection and installation of insulation.

SEWER MAINTENANCE AND REPAIR

When you are working with sewers, most of your troubles are with stoppages and breaks, probably stoppages. A common cause of stoppage in a sewer system is tree roots. Other causes include sand, gravel, and greasy or tar-related materials. A lot of sand, gravel, or just plain mud reveals a broken or loose sewer joint or pipe. Explosions in sewers are not uncommon and should be guarded against. Check with your local safety office for the most current regulations and information.

Systematic inspection and maintenance permit early correction of faults before major defects and failures develop. Trouble calls concerning stoppages or slow drainage are received occasionally. The first step in correcting the trouble is to determine the cause.

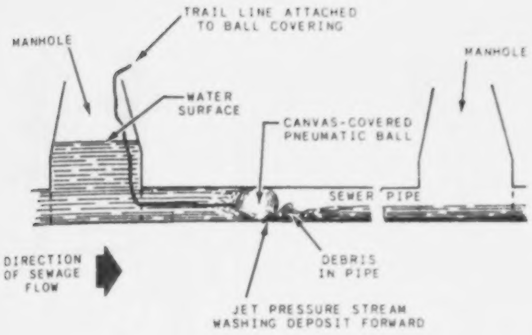
A sewer line can be inspected from manhole to manhole by using a flashlight or a reflecting mirror—or both. One person acting as an observer can look up the sewer line toward the flashlight held by the second person in a preceding manhole. Thus the condition of the line can be noted to determine whether roots or other obstructions need cleaning out.

Before entering a manhole, ensure the air is safe. If not, purge or use a fresh air pump. Sewage gases are very toxic as well as explosive. Routine sewer maintenance includes flushing, cleaning, and immediate repair of defective sewers. Information pertaining to flushing, cleaning, and repairing sewers is given below.

FLUSHING

Flushing helps remove loose organic solids and sand or grit deposits from sewers. Flushing is not an efficient method of sewer cleaning unless a high velocity can be maintained between manholes on a short run; in other words, you depend on the high velocity for complete scouring action of the sewer. Flushing may be done by a number of methods, two of which are with a fire hose and with a pneumatic ball.

When flushing with a fire hose, you need enough fire hose to reach between manholes. When using this method, string a rope or light cable through the sewer with sewer rods if a plain fire nozzle is used. Start at the upper end of the system and draw the flowing nozzle through the sewer. If a self-propelling turbine type of nozzle is used, the rope is not required. Try to use 2 1/2-inch fire hose discarded by the fire department. Paint the sewer-flushing hose at the ends with an identifying color to prevent use for emergency potable water connections.


TRAIL LINE ATTACHED TO BALL COVERING
MANHOLE
MANHOLE
WATER SURFACE
CANVAS-COVERED PNEUMATIC BALL
SEWER PIPE
DIRECTION OF SEWAGE FLOW
DEBRIS IN PIPE
JET PRESSURE STREAM WASHING DEPOSIT FORWARD

87.24

Figure 4-15.—Ball method of sewer flushing.

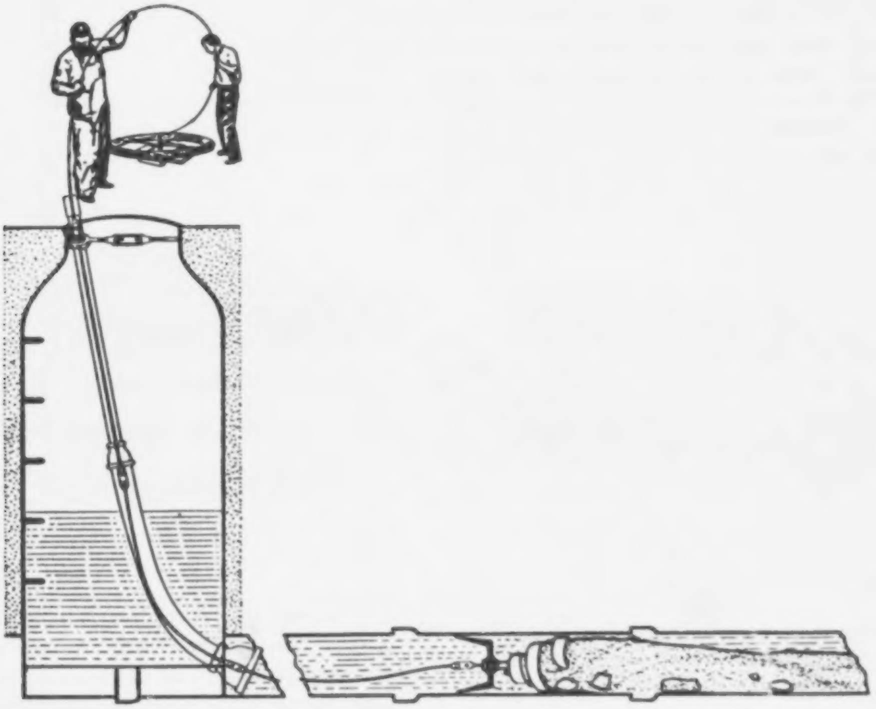
In pneumatic-ball flushing, inflate a light rubber ball, such as a beach ball or volley ball bladder, to fit snugly in the sewer, and place it in a small canvas or burlap bag with a light rope attached. Place the ball in the sewer, hold the line until the sewage backs up in the manhole, and allow the ball to move to the next manhole. When an obstruction is reached, the pressure pushes the ball against the crown of the sewer, causing a jet at the bottom. (See fig. 4-15.) As much as 4 miles of sewer can be cleaned in 8 hours by this method, and it works for sewers up to 30 inches in diameter. A wooden ball with a diameter of 1 inch less than the sewer can also be used. Where sewage flow is low, the addition of water to the upper manhole may be required.

In the sand cup method, a sand cup with an auger is attached to flexible steel sewer rods to run through the sewer (fig. 4-16). The rubber cup is perforated to provide flushing action.

CLEANING

In routine sewer cleaning, the usual way is by putting a tool through the line to indicate a clean sewer, by removing partial obstructions, or by determining the necessity for a detailed job, such as grease removal, root cutting, or sand removal.

Sectional wooden sewer rods, to which a variety of end tools may be attached, have been



54.393

Figure 4-16.—Sand cup and auger used with flexible steel rods.

used in sewer cleaning for many years. End tools for piercing an obstruction first, and cutters and scrapers for root and grease removal are available. Rods are pushed into the sewer from the bottom of a manhole. A device, as shown in figure 4-17, is useful for pushing the rods. Wooden rods are useful for stringing a cable through a partially obstructed sewer.

Another method of sewer cleaning is to use lightweight, spring-steel sectional rods coupled into a continuous line with several types of augers and sand cups as end tools. (See fig. 4-18.) The tool and rod are fed into the sewer until the obstruction is reached; then the obstruction is removed by the following methods: by twisting the rod by hand, by using a small gasoline engine, or by an electric motor drive unit.

NOTE: When using power-driven equipment, ensure that it is maintained under the manufacturer's recommendations.

Flushing methods described in the previous section remove all but heavy sand deposits. Accumulated sand and grit dislocated by flushing should be removed from the sewer at a manhole. A sand trap, made from a stovepipe ell and sheet metal to fit the sewer pipe, may be used, as shown in figure 4-19, to collect the sand. Commercial traps are available with adjustable slots to lower the water level below the top of the trap. Sand is removed by scoops or buckets.

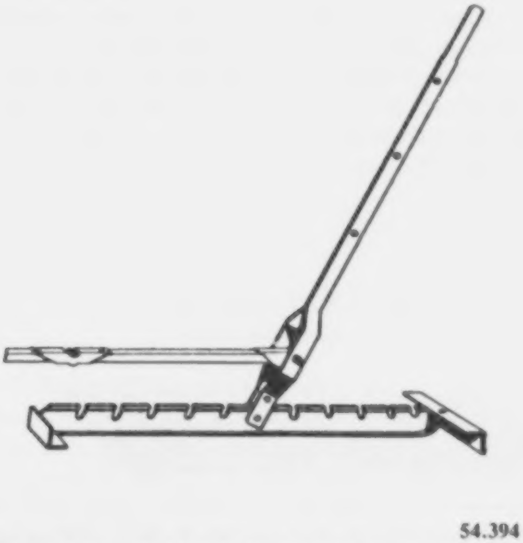


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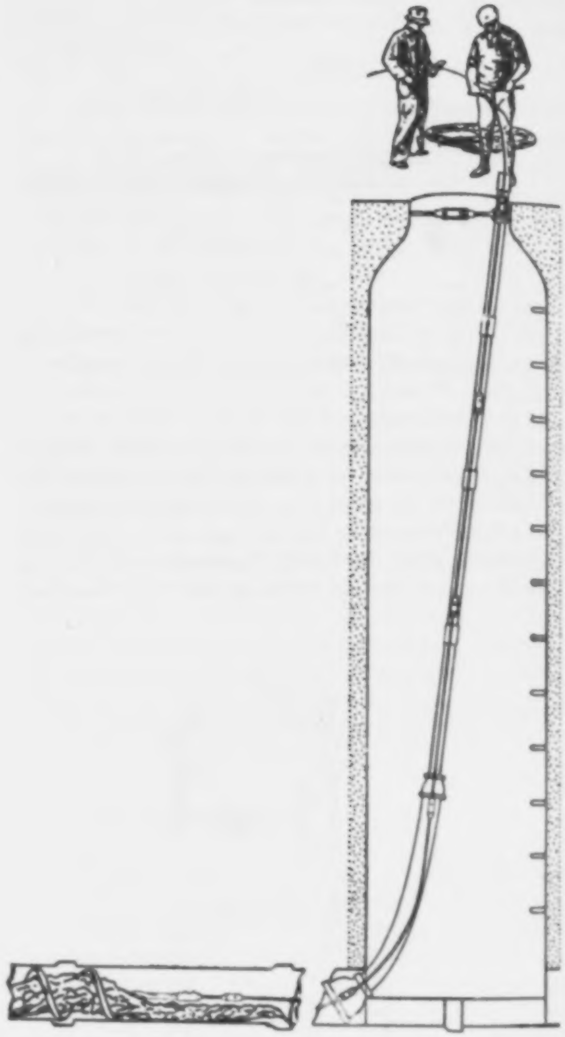
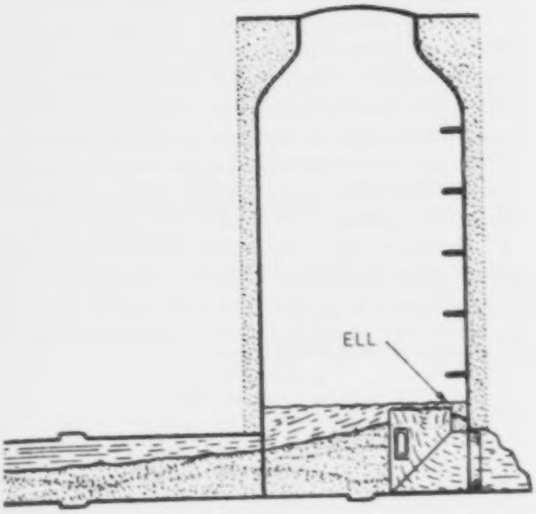
Figure 4-17.—Pushing device for wooden sewer rods.



54.395

Figure 4-18.—Root removal by steel rod and auger, manual operation.

For heavy sand deposits, a cable-drawn bucket is used, especially for storm sewers and larger sanitary sewers. The cable may be pulled by a hand winch, by a power winch, or by a truck with the cable through an anchored sheave. The sewer can be damaged if the bucket catches on misaligned joints, improper house connections, or



54.396

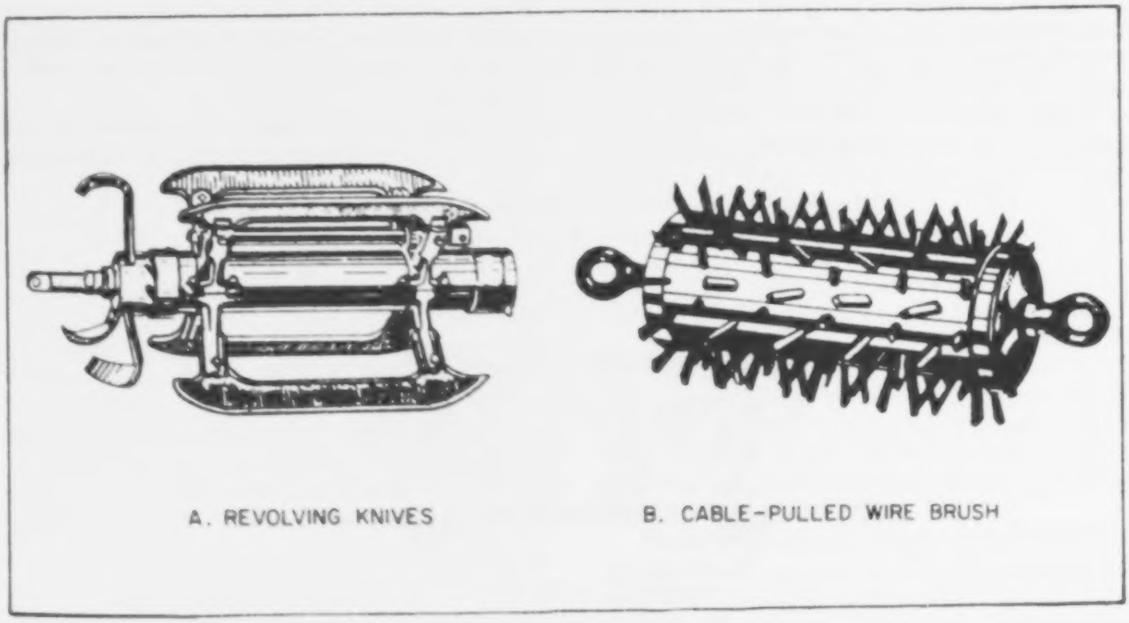
Figure 4-19.—Sand trap.

other fixed obstructions, especially with power-driven buckets.

Turbine-driven tools (fig. 4-20) clean sewers with difficult obstructions and grease coatings. These tools are powered by water under pressure from a fire hose. The tool and hose are pulled through the sewer by a cable.

Various types of power-driven sewer-cleaning machines are available. These machines normally have a 3/4-horsepower electrically reversible motor and weigh about 90 pounds. They are especially designed for clearing sewer pipelines, ranging from 1 1/2 inches to 10 inches in diameter and up to 200 feet in length. Some have a cable counter indicator, so the operator knows the distance the tool is in the line. Others have a headlight to aid you in working the dark areas.

A major difficulty with sewer systems buried in the ground is tree ROOTS. These are hard to detect just by looking in the manholes. With trees growing rather close to a sewer line, you can expect roots to cause a break in the line. Such trees as poplars, willows, and elms are the most troublesome when it comes to root growth. When these trees are growing within 100 feet of a line, you can look for trouble from roots sooner or


A. REVOLVING KNIVES

B. CABLE-PULLED WIRE BRUSH

54.397

Figure 4-20.—Turbine-driven tools.

later. Take a close look at figure 4-21 which shows tree roots penetrating a line.

One method for use in removing tree roots in a sewer is to apply copper sulfate (blue vitriol). Another is to use cable-drawn scrapers; these may be homemade. (See fig. 4-22.) Try copper sulfate first, since this is the most economical.

Stoppage can be detected by the nature of the flow of sewage and also by the conditions in the bottom of the manhole. Where stoppage is due to roots, sewage backs up into the next manhole above in periods of greatest flow during the day and recedes in periods of low flow. This condition may exist for days or possibly weeks before the sewage begins to overflow the top of the manhole and run into the street. By throwing in the copper sulfate crystals while the sewage is still flowing, a sufficient concentration of the poison usually reaches the seat of the trouble to eliminate it before the stoppage is complete. Remember, it is useless to apply copper sulfate in a sewer that is completely stopped. Unless there is at least a small flow of sewage through the obstruction, there is no chance for contact between the roots and the copper sulfate solution. Sewer rods are the only remedy. This starts some flow through the line and allows the copper sulfate to reach the roots. The procedure is to kill only the small roots that enter the sewer and not the great mass of roots branching from it; then reach the feeder root with the killing chemical. The flow pulling on the large, heavy brush causes the weakened base root to break. There is no set rule as to the exact quantity of crystals required for good results. But, the ideal condition seems to be that a small flow of sewage, say from 5 to 10 gallons per minute, is trickling through the mass of roots. In cases like these, a handful of the crystals applied in the manhole directly upstream from the stoppage can relieve the obstruction. When the flow is greater, as determined from looking in the manhole just below on the downstream side of the stoppage, greater quantities and possibly repeated applications are necessary. It is the time of contact of the chemical with the roots that is important rather than the amount of the chemical. If copper sulfate fails to remove the tree roots, then use power-driven or cable-drawn scraping and cutting tools.

REPAIRING

Ensure that sewer breaks, severe obstructions, and other causes of sanitary hazards are repaired at once. The cause of trouble should be found where possible and repairs made to prevent recurrence. Thus substantial bedding must be provided in replacing misaligned sewers, and backfill must be carefully placed and tamped. Leaking joints are preferably recaulked with a bituminous joint compound. Sewers beneath roads or railroads, crushed by settling, must be encased in concrete or replaced with cast-iron pipe unless the soil has become stabilized. In difficult situations, get technical assistance from higher authority.

Bypassing the sewage flow is usually required during repairs. The usual method is by blocking

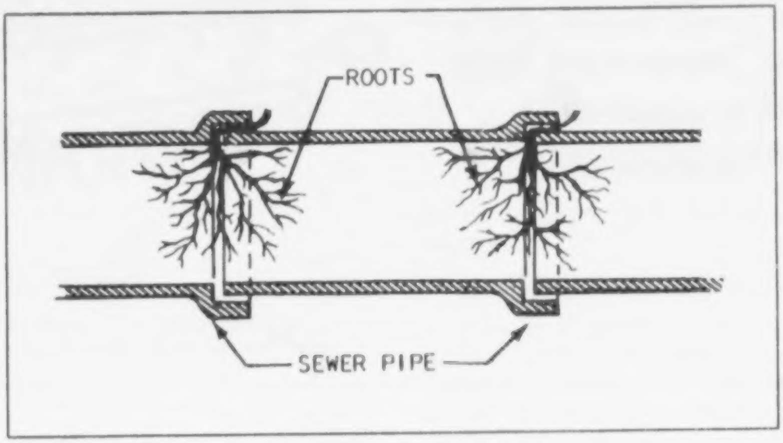
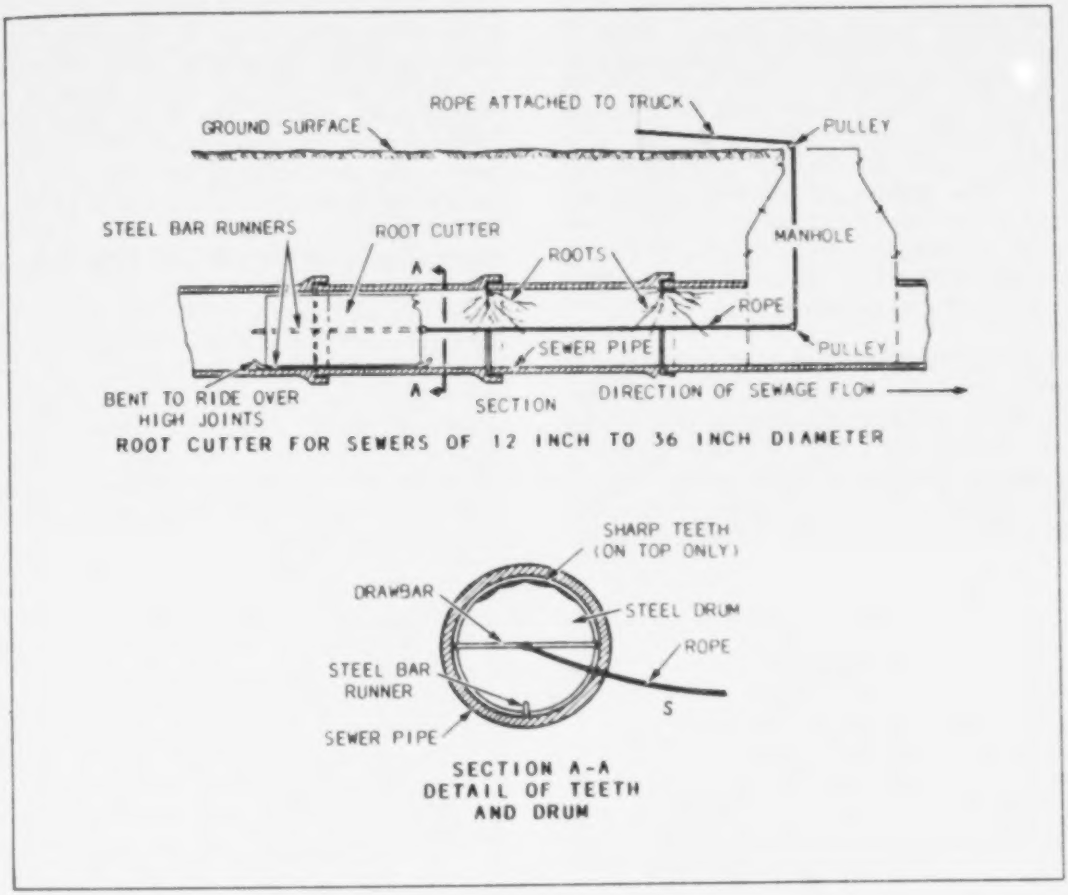


Figure 4-21.—Roots growing into sewer pipe.


ROPE ATTACHED TO TRUCK
GROUND SURFACE
PULLEY
STEEL BAR RUNNERS
ROOT CUTTER
MANHOLE
ROOTS
A
ROPE
SEWER PIPE
PULLEY
A
BENT TO RIDE OVER HIGH JOINTS
SECTION
DIRECTION OF SEWAGE FLOW
ROOT CUTTER FOR SEWERS OF 12 INCH TO 36 INCH DIAMETER
SHARP TEETH (ON TOP ONLY)
DRAWBAR
STEEL DRUM
ROPE
STEEL BAR RUNNER
S
SEWER PIPE
SECTION A-A
DETAIL OF TEETH AND DRUM

54.399

Figure 4-22.—Homemade cable-drawn scraping and root-cutting tools.

the upper manhole outlet with sand bags or an expandable rubber plug, using portable pumps to discharge the sewage to the lower manhole through a fire hose or a temporary pipeline.

Excavations must be braced and ladders provided under safety requirements for excavation, building, and construction. Adequate guards and warning signs must be placed around the excavations in roadways.

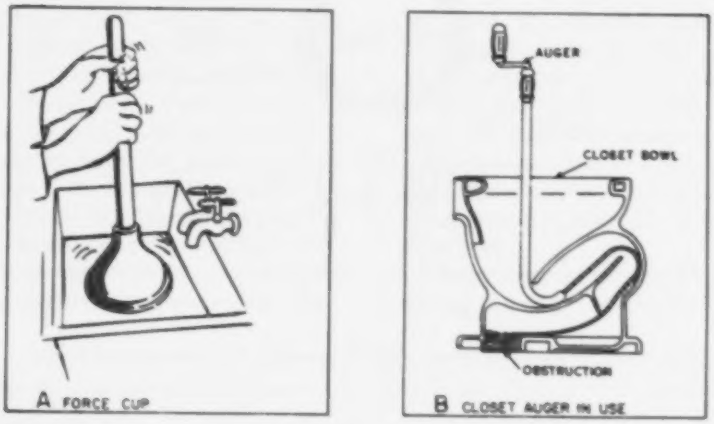
CLEARING STOPPAGES IN FIXTURES

Stoppages in fixtures are usually caused by materials lodged in the drain, trap, or waste line. Obstructions often can be removed by manually operated devices, by chemicals, or both. The method depends upon the seriousness and nature of the stoppage. The obstruction should be entirely removed and not merely moved from one place to another in the line. After the stoppage has been relieved, pour boiling water into the fixture to ensure complete clearance. Some of the methods used in clearing stoppages in fixtures are explained below.

When using a snake or sewer tape, keep track of the length of tape in the pipe, so you can determine the break or stoppage location. Also, with plastic pipe, exercise care not to use sharp ends to avoid cutting through the wall of a pipe or fitting.

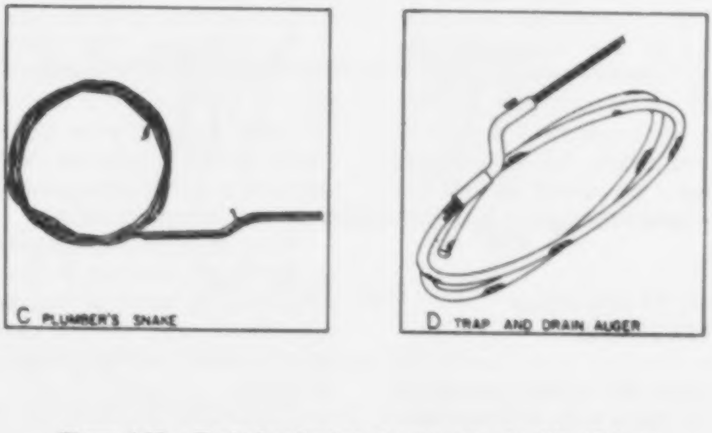
The FORCE CUP, or the PLUMBER'S FRIEND, is commonly used for clearing stoppages in service sinks, lavatories, bathtubs, and water closets. One type of force cup has a round, rubber suction cup, about 5 inches in diameter, fastened to a wooden handle. (See view A, fig. 4-23.) Then using the force cup, partly fill the fixture with water. Now, place the force cup over the drain opening and work the handle up and down to provide alternate compression and suction. The downward pressure or upward suction often clears the stoppage. Another type of force cup shaped to fit the opening of a water closet drain works more efficiently than the round type in clearing stoppages in water closets.

The CLOSET AUGER and PLUMBER'S SNAKE are used for opening clogged water closet traps, drains, and long sections of waste lines. (See views B and C, fig. 4-23.) The closet auger is a cane-shaped tube with a coiled spring "snake" inside and has a handle for rotating the coiled hook on the end of the snake. To insert the closet auger into the trap of the water closet, retract the coiled spring all the way up into the cane line curve of the closet auger. Hook the cane end, with its projecting hook, into the trap. Then start turning the handle to rotate the coiled spring as it is pushed down into the trap of the water closet. Rotate the handle continuously until the snake reaches the obstruction in the drain. Turn the handle slowly until the obstruction is caught on the coiled hook of the closet auger. Continue rotating the handle and pull back at the same time to bring the obstruction up into the water closet where you can remove it. NEVER assume that the water closet is clear after one object is brought up and removed. Insert the snake of the closet auger again and repeat the procedure until the closet auger passes down into the closet bend and branch. Withdraw the closet auger. Put four or five pieces of toilet paper in the water closet and flush them through the fixture to make sure that it is completely open.



A FORCE CUP

B CLOSET AUGER IN USE



C PLUMBER'S SNAKE

D TRAP AND DRAIN AUGER

29.210:213

Figure 4-23.—Tools for clearing stoppages in plumbing fixtures.

TRAP AND DRAIN AUGERS, such as the one shown in view D of figure 4-23, are used in clearing obstructions in traps and waste pipes. Trap and drain augers, also known as SINK SNAKES, are made of coiled, tempered wire in various lengths and diameters. They are very flexible and easily follow bends in traps and waste lines when pushed into them.

In clearing stoppages from lavatories, service sinks, and bathtubs, first use a plumber's force cup. If the obstruction is in the trap and is not cleared by the action of the plunger, clear the trap by inserting a wire or snake through the cleanout plug at the bottom of the trap. If the trap is not fitted with such a plug, remove the trap. Protect the finish of the packing nut with adhesive tape or wrap a cloth around the jaws of the wrench. Do not use a heavy steel-spring coil snake to clear traps under lavatories, sinks, or bathtubs. Use a flexible wire or spring snake that easily follows the bends in the trap. For example, a spring snake is used for clearing stoppages in floor drains. Remove the strainer or grate and work through the drain, or insert the snake through the cleanout plug opening nearest the obstruction.

Stoppage clearance tools should be used with caution. One reason why safety is so important is that a caustic chemical may have been poured into the stopped-up fixture in an effort to clear it. Caustic agents can cause serious injury if splashed into your face by a force cup. These caustic agents can also burn your hands while using a sink snake.

When manually operated devices fail to clear stoppages, there are several types of chemicals that can be used to dissolve or burn them out. These chemicals are discussed briefly below.

CAUSTIC POTASH (POTASSIUM HYDROXIDE)

Stoppages can be burned out by pouring a strong solution of this chemical and hot water into the line through the fixture opening. Pour the mixture slowly into the pipe through a funnel. Since this solution can cause serious burns, personnel must wear goggles and rubber gloves. Potassium hydroxide (caustic potash) damages glazed earthenware, porcelain, and porcelain-enameled surfaces.

CAUSTIC SODA (SODIUM HYDROXIDE)

Kitchen and scullery sink stoppages are often tough problems because of grease, oil, or fat washed down along with coffee grounds and small bits of garbage into the drain. Grease congeals and acts as a binder for solid particles and can usually be cleared by successive applications of a chemical cleaner. Effective cleaners include caustic soda (sodium hydroxide) with bauxite (an aluminum compound or ore) and other ingredients to intensify their action, or sodium hydroxide mixed with sodium nitrate and aluminum turnings. Adding water creates ammonia gas, which helps change grease to soap. This gas causes boiling and heating and helps dissolve the grease. When clearing a partially blocked drain, drop a small quantity of cleaner (from 2 to 8 ounces) into the open drain and follow with scalding hot water. Such cleaning agents cannot be satisfactorily used when the drain is completely plugged, since some flow is required to loosen the chemicals. A completely blocked drain must first be partially cleared with a plumber's snake before you can use the chemical cleaner effectively.

SAFETY

As a Utilitiesman, treat safety as part of your job. Some of the main safety precautions in plumbing are given below. This training manual does not cover all you need to know about safety. Learn all you can about safety through further study and on-the-job experience.

PIPE WORK

When acids are used in working on piping, see that they are kept in only glass or lead containers. Keep out from under hot joints while they are being poured. Ensure that hot lead is not poured over water or wet caulking.

When floors are oily and cannot be kept dry, they should be covered with sand or an oil-absorbent compound. Any type of tee, valve, or other service connection used on piping in maintenance or repair should be carefully checked to make sure it is designed to withstand maximum pressure.

SEWER WORK

Before beginning plumbing work on sewer jobs, pits, or tanks with the hazard of broken or leaking pipes, you should take the following two steps:

1. See that gas detectors, respirators, inhalators, standard gas masks, safety belts, lifelines, and blowers are on hand.
2. Test for explosive gas-air mixtures and the lack of oxygen in these locations before personnel enter them.

Where such hazards exist, the area must be controlled, and workers should don suitable respiratory equipment before entering the structure. Workers should receive instruction on the type of respirator for use in an emergency, and how to assemble and use this equipment properly.

At least two people should be assigned to each sewer job where there may be a hazard of broken or leaking pipes. One person should always be in a relatively safe position and be prepared to help in an emergency.

To help dissipate toxic or flammable gas in a sewer or underground sewage pumping plant, remove the manhole cover several minutes before a worker descends. Additional precautions relating to sewer work are given in chapter 7 of this training manual.

PROTECTIVE CLOTHING AND EQUIPMENT

Wear goggles, gloves, and other protective clothing in all pipe-fitting, pipe-handling, and plumbing work, particularly when you are handling hot metal or acid or if flying material could injure your eyes. When using compressed air to clean out sand, dirt, or scale from pipes before installation, you should wear goggles.

Wear flameproof garments when using blowtorches, welding torches, or similar tools. Plumbers should wear heavy coveralls and leggings that cover the instep to protect against hot lead; if unavailable, the regular working uniform may be acceptable.

When entering deep tanks, deep sewers, and other deep underground structures, you should wear a safety belt and a lifeline.

Use portable blowers for tank, pit, or manhole work where you suspect noxious gases, vapors, or a lack of oxygen. These blowers should have vaporproof, totally enclosed motors or nonsparking gas engines. Place the blowers at least 6 feet away from the opening and on the leeward side protected from wind, so they do not ignite flammable gas.

TOOLS

The following precautions apply to tools in general. Since pipe wrenches are one of the plumber's most important tools, precautions for these tools are in the following section.

Keep tools and appliances in good condition. Replace worn tools. Check hammer handles frequently; do not use hammers with broken or cracked handles. Also, do not let tools or materials clutter up the floor and become stumbling hazards. Pick up pieces of scrap pipe promptly and dump them in the scrap bin or scrap tubs for the next pickup.

Vise jaws should be used to grip material securely. When threads are being cut and during backing off operations, hold the stock firmly. Protect freshly cut threads with caps or couplings whenever possible. Guard against sharp burrs or fins. When operating a pipe-threading machine, determine the clearance of the pipe before starting the machine.

You should NEVER drop a cold ladle or other cold material into a pot of molten lead. It will explode.

PIPE WRENCHES

Never use an extension on a pipe wrench. The wrench was not made to handle this strain. Be sure there is plenty of clearance if the wrench should slip. Ensure that an adjustable pipe wrench faces forward in the direction the handle is to turn. When you use it in that way, an adjustable wrench can withstand the greatest force, because the pulling force is applied to the stationary jaw side of the handle. Also an adjustable wrench should always bite near the middle of the jaws, because there are teeth in front if the wrench slips. Do not overwork small wrenches, avoid side strain, and never use them as hammers.

PIPE HANDLING

Workers should wear leather or leather-faced gloves when handling pipe. They should also stand to one side when pipe is being unloaded from a truck or railway car.

Pipe should be piled so the ends are even and do not project into walkways. Pipe should be stacked straight; that is, not crossed. Pipe should not be piled directly on the bare ground; racks or dunnage should be provided.

Pipe should always be blocked to prevent it from rolling. Where practical, store pipe on specially designed racks.

When lifting heavy pieces of pipe, bend your knees, keep your back line as vertical as possible, and hold the load close to your body; straighten your knees and pull the load up directly over your feet. Lift with your legs, not with your back. Pipe should be carried with the forward end up to clear the heads of other people nearby. When pipe is transported on a vehicle, a red warning flag should be placed on the projecting ends.

When the crew is carrying a long and heavy pipe, each member should try to work as a team while observing the following precautions:

1. Each member of the crew should understand the signals for lifting and lowering.
2. Members should ensure that their feet are in the clear.
3. When needing tools, use either tongs or a carrying bar with a U-shape bend to fit the pipe. When the crew is carrying a length of pipe at shoulder or waist level, each member should carry it on the same side.
4. Take a firm grip on the lifting bar or tongs.
5. Lift the pipe when the supervisor or co-worker gives the signal. All members of the crew should lift and move together.
6. Carry the pipe without sudden starts or stops; move slowly and place your feet firmly.
7. Stop at the appointed place and wait for the supervisor's or co-worker's signal to lower the pipe.
8. Lower the pipe carefully, bending at the knees as in lifting, and lower slowly along with the other members of your crew.

Use caution in handling THREADED pipe. The threads are always sharp and cut flesh easily. Do NOT put your hands inside a pipe.

When removing pipe, work from the top end of the pile as much as possible. Pipe larger than 2 inches in diameter should be handled by means of a hardwood pipe stick. Use block and tackle, chain falls, or other lifting devices, where appropriate, when handling heavy pipes and fittings.

EXCAVATIONS

Maintenance operations on distribution systems may often involve excavation. Some precautions in making excavations are as follows:

- Wear a protective hat when working in a trench.

- Keep a safe distance from other workers to avoid striking them with tools.

- Do not jump into a trench, but sit on the shoulder and slide in if the trench is shallow. Use ladders where required; for example, a trench that is 5 feet or more in depth. Before climbing out of a trench, look in all directions for traffic danger.

- Remove earth and other material to avoid overhanging banks. Do not go under an overhanging bank and, when working near one, exercise caution. To remove an overhanging bank, work from one side to the center, always facing the point of danger.

- Where necessary, shore trench walls.

- When undercutting, provide adequate bracing and restrict the public from braced areas.

- Where practical, place excavated material at least 2 feet away from the edge of the excavation; otherwise, provide bracing.

- Keep tools, working material, and loose objects away from the shoulder of the trench.

GAUGES

Gauges are delicate instruments and require care and attention. They are most important in the safe operation of boilers, air conditioning and refrigeration systems, or compressed-air systems; they tell you what you need to know about water, heat, and pressure conditions, and eliminate guesswork.

Proper care of gauges should include the following:

1. Keep the dials and face clean.
2. Have the gauges well lighted to make the correct reading easier to take.

3. Keep the covers tight, and replace broken glass promptly.

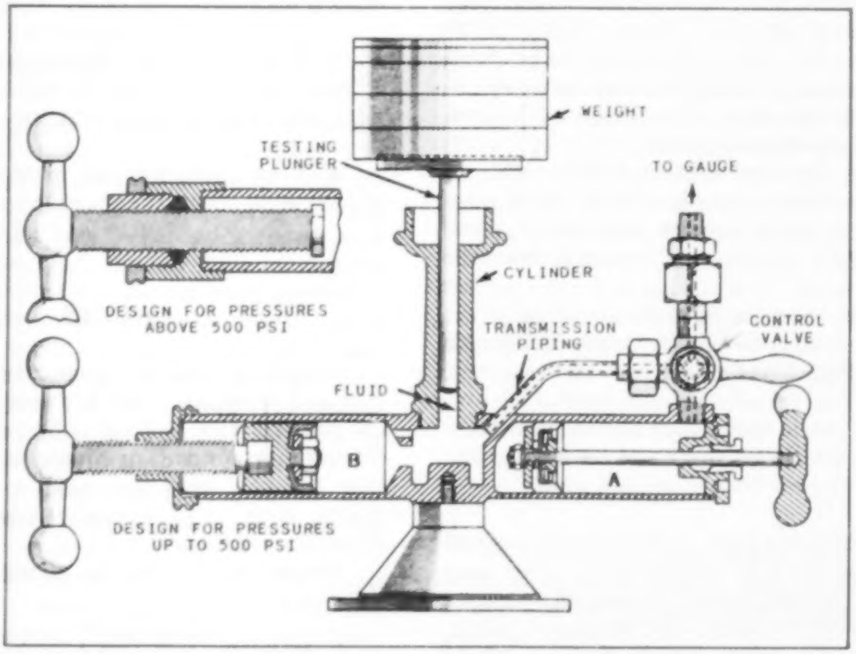
4. Protect the gauges as far as possible from vibration, excessive temperatures, corrosive liquids, and rapid changes in pressure.

TESTING OF PRESSURE GAUGES

Whenever you believe that a gauge is not accurate, test it with a dead-weight tester. Figure 4-24 shows such a tester. In this testing device, the gauge under test is subjected to pressure by applying weights to a plunger. The plunger is accurately fitted into a vertical cylinder that contains a water-base hydraulic fluid. (Mineral oil or other petroleum products must NEVER be used in the dead-weight pressure gauge tester.) Weights are applied to the plunger, and the pressure is transmitted to the fluid and then to the gauge by way of transmission piping and a control valve. The plunger itself exerts a known pressure (usually 5 psi). Additional weights are provided in sizes that exert pressures equal to 5, 10, and 20 psi.

In figure 4-24, notice that there are two horizontal cylinders and a main vertical cylinder. The plunger in Cylinder A pumps hydraulic fluid into the instrument when it is first filled. The plunger in Cylinder B exerts enough force on the fluid so the testing plunger maintains the weight platform in position about 2 inches above the top of the vertical cylinder. At the beginning of the test, the plunger in Cylinder B should be screwed out as far as it will go so Cylinder B (as well as the main cylinder) fills with fluid. If the weighted test plunger is pushed too far down at anytime during the test, the plunger in Cylinder B should be screwed in as far as necessary to force the test plunger up so it will have freedom of movement.

To test a pressure gauge in the dead-weight tester, connect the gauge to the apparatus and fill the tester with the proper water-base hydraulic fluid, if necessary. (Some testers of this type are designed to be kept full of fluid at all times, but others require filling before each use.) Then level the tester. Apply weights to the testing plunger, as required, and check the pressure gauge readings for accuracy. The plunger should be gently rotated, as each weight is added, to ensure its freedom of movement. If the gauge reading increases by the proper amount as each weight is added and if the gauge reading is equal to the



38.210

Figure 4-24.—Dead-weight pressure gauge testing apparatus.

pressure represented by the total weight added, the gauge is accurate. If the gauge is not accurate, it must be adjusted to read correctly.

ADJUSTMENT OF PRESSURE GAUGES

When a Bourdon-tube pressure gauge is inaccurate, the following adjustments should be made:

1. If the pointer travels too far or not far enough as each weight is applied, change the ratio of movement between the Bourdon tube and the pointer. The movement of the sector gear meshes with a pinion on the pointer spindle. Lengthening the distance between the spindle and the link connection to the sector gear reduces the amount of travel to the pointer. Shortening this distance increases the amount of travel.
2. If the amount of travel is correct as each weight is added but the total reading is wrong, the pointer must be reset. Gauges of recent design have a countersunk split-head screw in the dial for setting the pointer. On some older types of gauges, the pointer must be pulled and reset. Pointer pullers are supplied with the gauge-testing apparatus.
3. If the gauge cannot be made to read correctly over the entire scale, it should be adjusted so the reading is correct at the working pressure. A table or curve should then be made that shows the corrections required for other readings.

From time to time, you may be required to adjust the diaphragm type of air pressure gauge (fig. 4-25). The zero adjustment on these gauges should be checked frequently. Each gauge of this type has a three-way cock that can be turned to shut off the gauge without disconnecting the gauge piping. When the handle of the three-way cock is at right angles to the valve body, the gauge unit is open to the outside air pressure, and the reading on the scale should be zero. When the handle of the cock is parallel to the valve body, the gauge is open to the pressure in the line.

A zero adjusting screw is provided either below the gauge or on one side of the gauge. Turn this screw in or out to bring the pointer to zero while the handle of the three-way cock is at right angles to the valve body. After making this zero adjustment, restore the gauge to service by turning the cock handle so it is again parallel with the valve body.

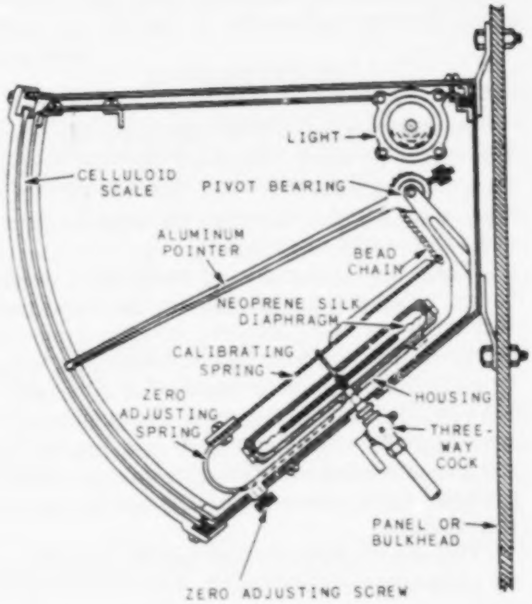


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Figure 4-25.—Diaphragm type of air pressure gauge.

MINOR REPAIR OF PRESSURE GAUGES

If you are required to replace any part of a pressure gauge, handle the mechanism carefully so none of the elements are bent or distorted.

You may occasionally have to replace the diaphragm in a diaphragm type of air pressure gauge (fig. 4-25). First, disconnect the pressure line below the unit. Remove the outside zero adjustment screw and the three-way cock (with its coupling), and remove the unit from its case.

Disassemble the unit by compressing the small spring on top of the calibrating spring to loosen the retaining pin. Remove the stem that holds the calibrating spring, and remove the screws (usually 10) around the edge of the diaphragm housing. The oil diaphragm can then be lifted out.

Clean both surfaces of the housing. Apply a small amount of gasket cement to the edge of the lower housing, and immediately place the new diaphragm-gasket assembly over the edge of the lower housing. Replace the top housing. Tighten the screws, being careful to draw them up uniformly. Replace the calibrating spring stem, compress the spring, and insert the retaining pin in the stem. Then replace the unit in the case. The gauge is ready for service

SCAFFOLDING

As the working level of a structure rises above the reach of crew members on the ground, temporary elevated platforms called SCAFFOLDING are erected to support the crew members, their tools, and materials.

There are two types of scaffolding in use today: wood and prefabricated. The wood types include the swinging scaffold, which is supported on the ground. For information concerning wood-type scaffolding, refer to *Builder 3 & 2*, volume 1, NAVEDTRA 10646, chapter 5. The prefabricated type is made of metal and is put together in sections as needed. As a Utilitiesman, you will be working more with the prefabricated type of scaffolding.

This section only provides general information on prefabricated scaffolding. For further information pertaining to the particular details of scaffolding, consult *U.S. Army Corps of Engineers' Safety and Health Requirements Manual*, EM 385-1-1.

PREFABRICATED SCAFFOLDING

Several types of patent-independent scaffolding are available for simple and rapid erection, as shown in figure 4-26. The scaffold uprights are braced with diagonal members, as shown in figure 4-27, and the working level is covered with a platform of planks. All bracing must form triangles, and the base of each column requires adequate footing plates for bearing area on the ground. The patented steel scaffolding is usually erected by placing the two uprights on the ground and inserting the diagonal members. The diagonal members have end fittings that permit rapid locking in position. The first tier is set on steel bases on the ground, and a second tier with the bottom of each upright locked to the top of the lower tier. A third and fourth upright can be placed on the ground level and locked to the first set with diagonal bracing. The scaffolding can be built as high as desired, but high scaffolding should be tied to the main structure.

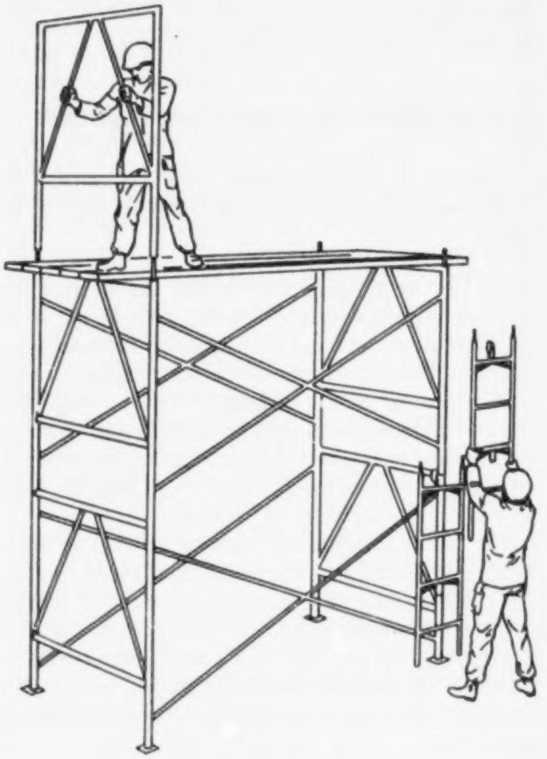

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Figure 4-26.—Assembling prefabricated independent-pole scaffolding.

Steel and aluminum scaffolding is used to speed up construction and maintenance operations. For interior work and erection, there are many types. This type of scaffolding is used around many construction sites because it can be disassembled and transported whenever necessary. They are mounted on steel casters with brakes and adjustable supports, which permit quick movement and positioning of each tower. This scaffolding is equipped with special, trussed planks, 12 feet long, which are placed to enable crew members to be within comfortable and safe working distance of all working space.

Prefabricated scaffolding of this type comes in three categories: light, medium, and heavy duty. Light duty scaffolding has nominal 2-inch outside diameter steel-tubing bearers. Posts are spaced no more than 6 to 10 feet apart. The load it can handle is 25 pounds per square foot. Medium duty scaffolding normally uses 2-inch outside diameter steel-tubing bearers. Posts should be spaced no more than 5 to 8 feet apart. If 2 1/2-inch outside diameter steel-tubing bearers are used, posts are spaced 6 to 8 feet apart. The load it can handle is 50 pounds per square foot.

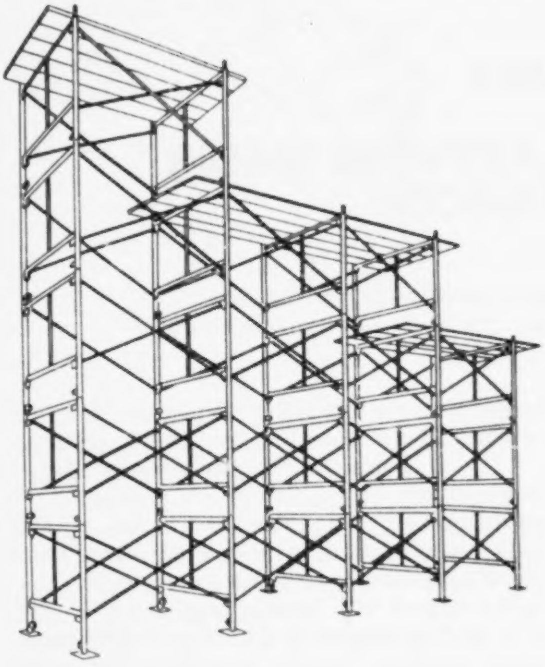

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Figure 4-27.—Prefabricated independent-pole scaffolding.

Heavy duty scaffolding should have bearers of 2 1/2-inch outside diameter steel tubing with the posts spaced not more than 6 feet 6 inches apart. The load it can handle is 75 pounds per square foot.

To find the load per square foot of a pile of materials on a platform, divide the total weight of the pile by the number of square feet of platform it covers.

SAFETY

The following safety precautions must be observed by all persons working on scaffolds or tending other persons who are working on scaffolds. Utilitiesman petty officers must not only observe the safety precautions themselves, but they must also issue them to their crew and ensure that the crew observes them.

- Scaffolds must be kept clear of accumulations of tools, equipment, materials, and rubbish.
- No scaffold may be used for the storage of materials in excess of those currently required for the job.
- Tools not in immediate use on scaffolds must be stored in containers to prevent tools left adrift from being knocked off. Tool containers must be lashed or otherwise secured to the scaffolds.
- Throwing objects to or dropping them from scaffolds is absolutely prohibited. Hand lines must be used for raising or lowering objects that cannot be passed hand to hand.
- A standard guardrail and toeboard should be provided on the open side of all platforms 5 feet or more above ground; otherwise, safety belts tied off to safety lines must be used.
- No person should remain on a rolling scaffold while it is being moved.
- All scaffolds must be maintained in safe condition, and they must not be altered or disturbed while in use. Personnel must not be allowed to use damaged or weakened scaffolds.
- Access to scaffolds must be by standard stairs or by fixed ladders only.
- When scaffolding is being dismantled, it should be cleaned and made ready for storage or use. Scaffolding that is not ready for use should never be stored.

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CHAPTER 5

PRIME MOVERS, PUMPS, AND AIR COMPRESSORS

Learning Objective: Identify types and uses of prime movers, pumps, and air compressors and the safety precautions related to operation.

Since you will use prime movers, pumps, and air compressors, you will need to know how to install, operate, and care for this gear.

Because of the many types of prime movers, pumps, and air compressors used throughout the Navy, the information presented on operating procedures and maintenance requirements in this chapter is brief and general. The emphasis is on fundamental operating principles and parts of prime movers, pumps, and air compressors, and some of the operating problems you may experience.

Specific operator maintenance schedules, logs, and reports are developed in each local command. Each local command also maintains a file of manufacturer's instructions, parts lists, drawings, and diagrams for all equipment installed or used in that command. Taken together, these maintenance schedules, manufacturer's instructions, and so on, provide you with detailed information on operating procedures and maintenance requirements. In all cases, get to know these guides before attempting to operate and maintain the equipment for which you are responsible.

There are several Navy training publications you need to be aware of because they are important. Although these books are described as basic texts, the information they contain can help you better understand the equipment covered in this chapter.

To know more about the operating principles and construction of electric motors, obtain a copy of module 5, *Introduction to Generators and Motors*, one of the textbooks in the Navy Electricity and Electronics Training Series (NEETS). *Basic Machines*, NAVPERS 10624-A, explains the operating principles and construction of internal combustion engines. For pumps and air compressors, *Fluid Power*, NAVPERS 16193-B, discusses fluid physics, the construction and operating principles of pumps and air compressors, and covers valves, packing, fluid piping and tubing, and fluid temperature and pressure gauges.

PRIME MOVERS

A prime mover is a source of mechanical energy or power. The mechanical energy produced by the prime mover is transmitted to another machine or mechanism, such as a pump or air compressor, to do some form of useful work. In this sense, prime movers are sometimes referred to as driving equipment. The mechanism, or linkage, that transmits the mechanical power developed by the prime mover is called the drive. You probably know that electric motors and internal combustion engines are used as prime movers. In this chapter, a prime mover is treated as a separate topic, even though you will operate it and maintain it with some driven mechanism, such as a pump or air compressor.

OPERATION AND MAINTENANCE OF ELECTRIC MOTORS

Electric motors, as prime movers, receive electrical energy from some external source and transform it into the mechanical energy needed to turn out work. Electric motors are either direct current (dc) or alternating current (ac). Since most of the electrical power generating systems both ashore and afloat produce alternating current, only the ac motor is discussed.

Of the various types of ac motors available, you will work primarily with the rotating-field INDUCTION ac motor. The popularity of this motor is due largely to its reliability and simplicity

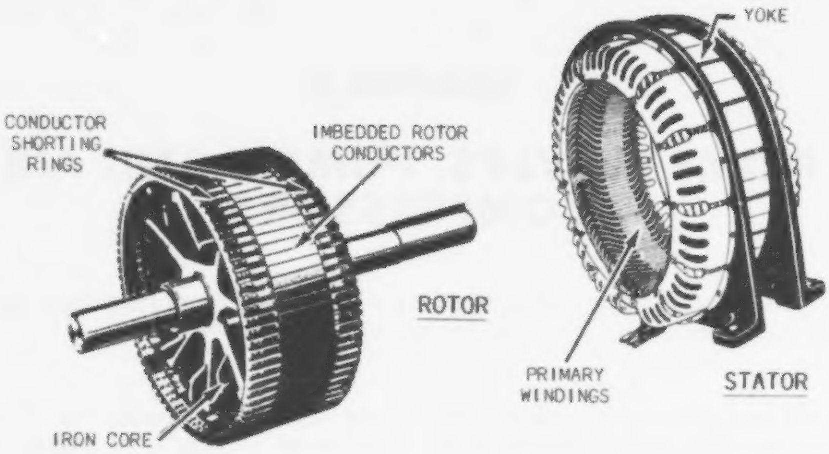

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Figure 5-1.—Rotor and stator assemblies of an induction motor.

of construction. The basic induction motor has two main assemblies or components—a ROTOR and a STATOR—shown in figure 5-1. The mechanical rotation of the rotor is produced through the principle of electromagnetic induction. Alternating current flows through the stator (a circular assembly of stationary coils or windings) which surrounds the rotor. The alternating current flow in the stator produces a constantly rotating magnetic field. This magnetic field induces a current flow in the conductors of the rotor (a cylindrical or drumlike assembly of copper bars mounted on a shaft). The induced current in the rotor then produces a magnetic field of its own. The magnetic field of the rotor is produced so that it opposes the magnetic field of the stator; that is, the two fields repel each other. This continuous repulsion of the rotor field by the stator field results in a continuous rotation of the rotor assembly around its axis or shaft. Thus, electrical rotation (in the stator) is transformed into mechanical rotation (in the rotor).

The rotational speed of the stator field remains constant unless the frequency of the electrical power source varies. The rotational speed of the rotor is also constant and is more or less independent of the workload imposed on it. This is not to say, however, that an induction motor cannot be overloaded. Under heavy or excessive loads, the motor tends to draw more current to maintain speed; this can result in overheating and burned-out windings.

Induction motors are usually named by the method of starting the motor. Two fairly common types of induction motors, classified in this manner, are the SPLIT-PHASE MOTOR and the CAPACITOR-START MOTOR. Split-phase induction motors are designed to operate on single-phase current. Induction motors require two or more out-of-time-phase currents to produce the continuously rotating magnetic field in the stator. For this reason, induction motors that must run on a single-phase power supply are provided with split-phase windings which make two phases of the single-phase current. Split-phase motors can be used to drive a variety of equipment, such as washing machines, oil burners, small pumps, and blowers. The capacitor-start induction motor is a variation of the split-phase motor, but it has a high capacity, electrolytic capacitor. Briefly, this device stores electricity to provide more power during the start.

There are a number of mechanical modifications to induction motors. The most important being (1) the splashproof motor; (2) the totally enclosed, fan-cooled motor; and (3) the explosion-proof motor.

The splashproof motor is constructed so dripping or splashing liquids cannot enter the motor. The motor is self-ventilated, but since moisture-saturated air may be circulated through the motor, the windings are made moisture resistant. Motors of this type are most often used to drive pumps and other machinery where the moisture content of the air is nigh.

The totally enclosed, fan-cooled motor has totally enclosed windings and rotor. Cooling air is circulated over the enclosure to carry away heat. This motor is used in locations where the surrounding air may contain a high proportion of dust, as in a carpenter shop.

The explosionproof motor is similar to the totally enclosed, fan-cooled motor, but is constructed to prevent any explosion within the motor from igniting combustible gases or dust in the surrounding air. This motor, therefore, is used in sewage treatment plants and at other locations as a safety consideration.

The operation and operator maintenance of electric motors has four main aspects: lubrication of moving or rotating parts, proper alignment of drives, safety, and cleanliness of windings and rotor. Pay careful attention to each of these factors to ensure motor efficiency and, in many cases, to prevent motor breakdown.

Lubrication

Electric motors can be fitted with a variety of bearings, such as sleeve bearings, roller bearings, and ball bearings. These bearings reduce friction. To remove the heat generated by friction, you must lubricant the bearings. The lubricant is usually either grease or oil. Many motors are equipped with ball bearings permanently lubricated or packed with grease when the motor is assembled at the factory. These bearings are usually covered with a nameplate which reads: DO NOT LUBRICATE. Most electric motor bearings, however, must be lubricated at frequent intervals. In such cases, the lubricant is fed to the bearings through a pressure fitting or grease nipple from a hand-operated grease gun. Or, the lubricant may be metered to the bearings from a grease or oil cup, which must be periodically turned or screwed down by hand to keep the bearings supplied with lubricant. (See fig. 5-2.)

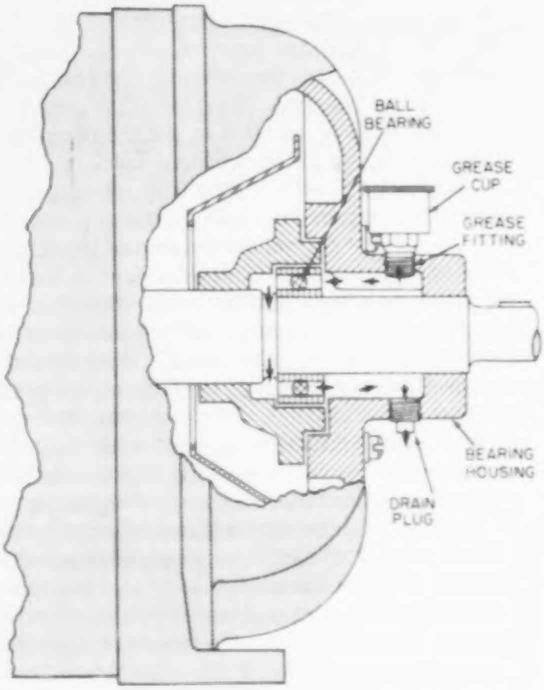

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Figure 5-2.—Grease-lubricated ball bearings.

Some rotating shafts are fitted with sleeve bearings which usually are soft brass cylinders that fit around the machine-shaft journal like a sleeve. In some installations, the lubricating oil is circulated through the sleeve bearings under pressure. Some sleeve bearings, however, may be lubricated by means of an oil ring or rings, as shown in figure 5-3. The weight of the ring hanging on the journal is enough to cause it to revolve as the shaft revolves. As the oil ring rotates, it dips into an oil reservoir directly beneath the shaft journal. The oil picked up by the ring is then

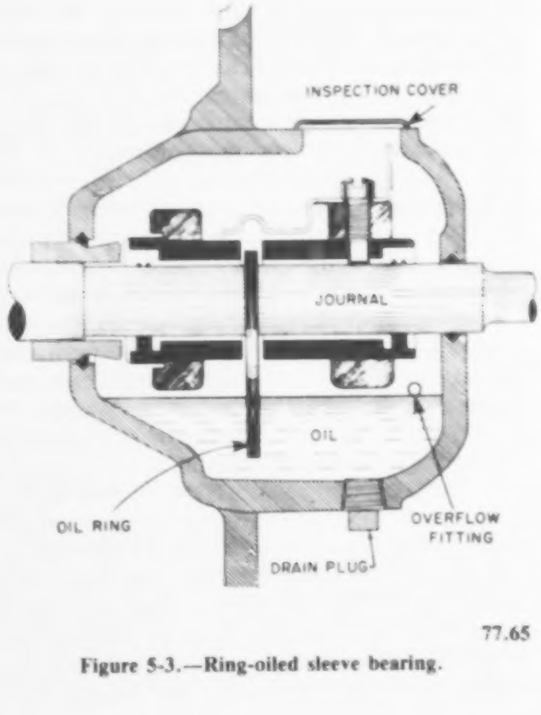

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Figure 5-3.—Ring-oiled sleeve bearing.

diffused along the shaft, between the shaft journal and sleeve bearing. Proper lubrication of ring-oiled sleeve bearings depends on maintaining a sufficient oil level in the reservoir. For this reason, most sleeve bearings have oil filler gauges or overflow fittings installed to aid the operator in maintaining the oil at a proper level.

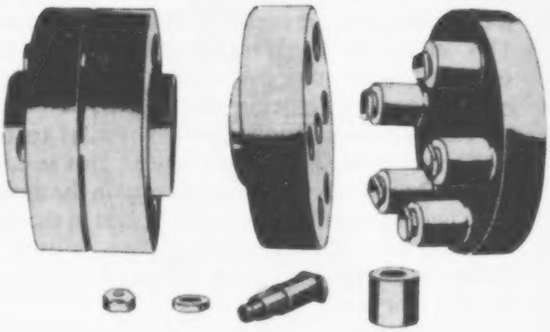
While the electric motor is in operation, the operator is required to make frequent checks and inspections for proper lubrication of bearings or bearings overheating. Check for heat radiated to the hand or watch thermometers. Note that one of the most frequent causes of bearings overheating is overlubrication, in particular, grease-lubricated bearings. Too much grease around the bearings insulates and seriously hinders the conduction of heat away from the bearing. The specific lubrication requirements and inspection procedures vary according to the type of bearings and the motor installation. Anyway, consult your local operator maintenance schedules and instructions for guidance. Other than the inspections cited, the operator should check for leaks of lubricants from the bearings, especially lubricant oozing toward the windings or other electrical conductors.

At less frequent intervals, maintenance schedules require additional and more detailed inspections for proper lubrication. This may involve dismantling parts of the bearing housing. Bearing housings and pressure fittings must be cleaned periodically. With grease-lubricated bearings, old grease must be flushed from the bearing with solvent and fresh grease added. Sleeve bearings must be examined at various intervals, and the oil reservoir flushed, cleaned, and refilled.

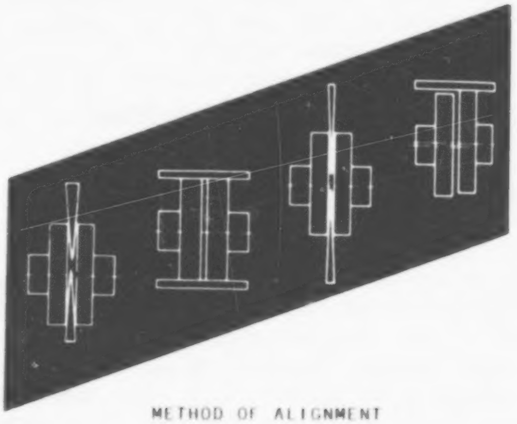
Maintenance and Alignment of Drives

The mechanism, or linkage, that transmits the motion and power of the prime mover to the driven equipment is the drive. The drive must be maintained and operated properly, since its alignment and mechanical efficiency affects both the prime mover and the driven equipment. Two fairly common types of drives used with electric motors are the flexible coupling and the belt drive.

The coupling shown in figure 5-4 connects or couples the shaft of the prime mover to the shaft of the driven equipment. The coupling is designed to permit very slight misalignment between the two shafts. This flexibility permits the coupling to absorb some of the torque, or twisting force, resulting from the inertia of the driven equipment when the motor is started and brought up to speed. However, any misalignment in excess of these small tolerances causes rapid wear of the coupling hubs and bushing pins, vibration of the shafts, and a reduction in the transmission of power from the prime mover. Vibration is transmitted through the shafts to moving or rotating parts of both the electric motor and the driven equipment. Vibration inevitably results in excessive wear of the various bearings that support the moving or rotating parts, which, in turn, results in more misalignment, vibrations, and wear. The point is that small vibrations, which at first may seem insignificant, can develop into major casualties and breakdowns.



ALLIS-CHALMERS FLEXIBLE COUPLING



METHOD OF ALIGNMENT

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Figure 5-4.—Coupling.

While the motor is in operation, check the coupling for any unusual noise or vibration. At prescribed intervals, maintenance schedules require the operator to check the alignment of the coupling with a straightedge, dial indicator, thickness gauge, or wedge, and realign the coupling as necessary. For detailed instructions relating to the realignment procedure, consult the manufacturer's instructions.

Various belt and pulley arrangements are also used as drives on electric motors. These belt drives are somewhat similar to the fan belt arrangements that drive the fan, water pump, and generator on automobiles. The belt, made either of rubber or leather, rides on grooved pulleys or sheaves; one sheave connected to the shaft of the prime mover and the other sheave connected to the shaft of the driven equipment. In this way, the rotation of the electric motor is transmitted to the shaft of the driven equipment.

Belt drive maintenance requires proper belt tension. If the belt is too loose or slack, the power of the prime mover is not transmitted efficiently. Belt slippage also results in excessive rubbing and wear of the belt on the sheaves. Sheaves worn or out of alignment can also contribute to excessive belt wear. Additionally, belt slippage can be caused by an accumulation of oil or grease on the sheaves. If the belt is too tight, on the other hand, the stress is transmitted to the bearings in the sheaves and along the shafts. This, of course, causes excessive bearing wear and misalignment.

A properly adjusted belt has a very slight bow in the slack side when running. When idle, the belt has an "alive" springiness when thumped with the hand. Lack of this springiness indicates too little tension. A belt that is too tight feels dead when thumped with the hand.

While the motor is in operation, you should visually inspect the belt drive periodically for any indication of improper tension or slippage. Also, be careful to keep the belt and sheaves clean and free of grease or oil at all times. At prescribed intervals, inspect the belt for fraying, cracks, or other unusual wear. You should also inspect and check the alignment of the sheaves. Excessive belt rubbing on the sheaves is an indication of belt slippage. Sheaves that are out of alignment are normally a result of excessive belt tension.

Occasionally, it may be necessary to replace a worn and frayed belt. If the drive has multiple belts, ALL the belts must be replaced with a set of matched belts. The belts in a matched set are machine checked to ensure equal size and tension.

In addition to the maintenance and inspections outlined above, the operator must test and inspect other items related to the motor, such as control switchboards, pilot lamps, alarms, and circuit breakers. Electrical connections and conductors must also be periodically inspected for proper insulation and security.

Safety

Because of the danger in working with electric motors, all safety precautions should be observed. In operating electric motors and in performing operator maintenance on electric motors, remember that you are working on a device which carries a force of energy that is not only useful but also deadly.

Cleanliness

This aspect of electric motor operation and maintenance is largely a matter of prevention rather than inspection and correction. As an operator, you must develop clean housekeeping and maintenance habits. Dirt, dust, and other foreign objects that accumulate on and inside an electric motor can reduce ventilation and foul moving parts. When dirt and grit accumulate on windings, the cooling or ventilation of these electrical conductors is seriously reduced. During the inspection routines, prevent lubricants and lubricant fittings from getting contaminated. Dirt in lube oil, in many cases, settles to the lowest point in the system before doing any extensive damage. However, dirt or grit that gets into lubricating grease can remain suspended indefinitely and result in abrasion of bearings and moving surfaces.

The maintenance schedule usually requires periodic inspection and cleaning of the rotor and the stator windings. Low-pressure compressed air can be used to blow out the dirt and dust. However, in the stator, this method can sometimes result in dirt being driven deeper into the windings. Instead, you should use vacuum suction. In fact, vacuum suction is always the preferred method for removing dust and dirt from stator windings, or from any other motor component when compressed air could force dirt and abrasive particles deeper into the mechanism. Accumulations of grease and oil can be removed with the proper type of petroleum solvent. In any case, consult local maintenance schedules and instructions for the specific and precise cleaning method.

INTERNAL COMBUSTION ENGINES

An internal combustion engine is a machine that produces mechanical energy by burning fuel in a confined space (the engine cylinder). The term applies to both diesel and gasoline engines.

The UT should have a basic knowledge of the principles of diesel and gasoline operation, since the Utilitiesman has to operate and hold first-echelon maintenance of the engine used to drive various types of pumps and compressors.

Operation and Maintenance of Diesel Engines

Diesel engines change heat energy into mechanical energy. Heat is developed when a mixture of compressed fuel and air burns inside a cylinder. A complete description of the internal combustion engine and its principles of operation is in chapter 13 of *Basic Machines*, NAVPERS 10624-A.

To keep diesel engines in peak operating condition, the operator must give careful attention to the following factors: prestart inspection, starting the diesel, securing the diesel, and operator maintenance.

Before a diesel can be started, the operator must perform a prestart inspection to ensure the engine is ready for operation. The specific inspection routine varies somewhat according to each engine installation. The basic procedure, however, requires the operator to inspect the engine for a sufficient supply of fuel oil, lube oil, and cooling water. The operator must also be alert for any leakage of these fluids. When replenishment of cooling water is necessary for the radiator, use clean or soft water to keep the engine water jackets and coolant circulating system free of sediment. If the engine is still hot from previous operation, do not add large amounts of cold water. Sudden cooling can crack cylinders and cylinder heads and cause unequal contraction of the structural and working parts and lead to seizing of the pistons. When topping off batteries, use distilled water.

Accessories and drives should be inspected for loose connections and mountings. If the diesel starting system is battery equipped, check the batteries for cracks and leaks, and ensure the battery cables and vent caps are clean and secure. As a safety precaution, inspect fire extinguishers for ease of removal, full charge, security, and cleanliness of valves and nozzles before starting the engine.

Diesel engines rely on some external source of power for starting. The starting mechanism may be an electric motor, an auxiliary gasoline engine, compressed air, or even a hand-cranking mechanism. Whatever system is used, the starter forces the pistons to reciprocate and compresses air drawn into the cylinders. When sufficient compression has been developed with the aid of the starter, the temperature of the air in the cylinders will be high enough to ignite the injected diesel fuel. Thus, internal combustion takes place and the engine begins to crank under its own power. Once the engine has been started, the operator must do the following:

1. Throttle the engine to normal (fast idle) warm-up speed. The diesel should not be permitted to slow idle for any appreciable length of time since, under these conditions, the engine-driven blower delivers an insufficient amount of air for complete combustion. This results in partially burned fuel oil forming heavy carbon deposits which foul the valves, the piston rings, and the exhaust system.
2. Immediately check the lube oil pressure gauge. If the gauge does not indicate positive and sufficient lube oil pressure within 30 seconds, stop the engine immediately and report the difficulty to proper authority.
3. Observe the temperature gauge during the warm-up period. The engine must not be placed under load until it reaches the proper warm-up temperature. Placing a cold engine under full load can result in serious damage to the engine because of poor lubrication at low temperature and uneven rates of expansion.

While the engine is in operation, other inspections and checks are required, such as checking of lube oil and fuel oil levels, filters and strainers, accessories and drives, and engine operating temperatures and pressures. Normally, the operator records the results of these inspections in an operating log.

When securing the diesel, if the engine installation permits, let the engine low idle without load for a short time before stopping to allow for a gradual reduction of engine temperature. Once the diesel has been shut down, the standby lube oil pump should be kept in operation for a short time to allow the lube oil to further cool the engine. The cooling water should also be kept circulating for 15 to 30 minutes to bring the working parts to a low temperature without danger of distortion from one part cooling faster than another.

While the engine is cooling, the operator must check to determine the need for adjustment, repair, and replacement or renewal of parts.

- Check fuel, oil, and water as in the prestart inspection.

- Check engine instruments or gauges for proper readings.
- Check accessories and drives as in the prestart inspection.
- Inspect air cleaners and breather caps.
- Inspect fuel filters.
- Inspect engine controls and linkage.
- Inspect the batteries as in the prestart inspection.
- Inspect all electrical wiring, insulation, and security of connections.

According to the prescribed maintenance schedules, the engine operator performs other inspections and maintenance duties. These maintenance routines occur at various intervals, some weekly, some monthly, some quarterly, and so on. The items listed below are intended to give you some idea of what is in the maintenance schedules.

- Disassembling and cleaning the air filters and breather caps
- Removing and cleaning the oil filter elements
- Inspecting the fuel lines, fuel filters, and fuel pump
- Cleaning the battery casings and terminal posts; checking for proper electrolyte level and specific gravity
- Inspecting, cleaning, and lubricating the generator; inspecting and testing the voltage and current regulator
- Inspecting and lubricating the starting mechanism
- Inspecting the radiator; inspecting the water pump, fan, and drive belts
- Inspecting the crankcase, valve covers, timing gears, and clutch housing
- Inspecting the cylinder heads and gaskets

Operation and Maintenance of Gasoline Engines

Like the diesel engine, the gasoline engine changes heat energy into mechanical energy. The physical construction of the gasoline engine is very much the same as that of the diesel. Pistons, cylinders, valves, connecting rods, a crankshaft, and an engine block are in each. A cooling system carries heat away; a lubrication system reduces friction of moving parts; an air system supplies air for combustion in the cylinders; and fuel system to supply fuel.

Most gasoline engines operate on the four-stroke cycle. (See fig. 5-5.) The difference between gasoline and diesel engine operation is

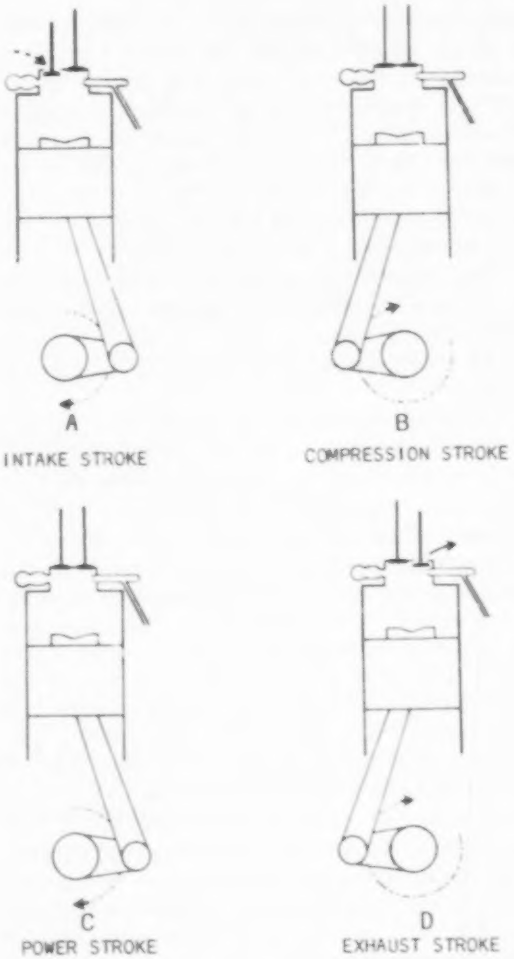

Figure 5-5.—Four-stroke cycle.

the method of introducing the fuel and air into the cylinders and the means by which the compressed fuel and air are ignited in the cylinders.

In a diesel engine, the air is admitted to the cylinder on the intake stroke of the piston, as shown in view A, figure 5-5. The fuel oil is sprayed into the chamber AFTER the air has been compressed. In the gasoline engine the fuel (gasoline) and air are mixed together BEFORE being admitted to the cylinder. The intake stroke of the piston sucks air through the air cleaner into the carburetor. In the carburetor, the clean air is mixed with gasoline (vaporized) from the fuel tank. The air and gas mixture continues on to the intake manifold which is connected to the cylinder head. An intake valve admits the air-gas mixture into the cylinder.

The diesel engine produces combustion by using the heat of compression, as shown in view B. In the gasoline engine, an electric SPARK is provided by the spark plug to ignite the air-gas mixture. Ignition occurs as the piston completes its compression stroke. The ignited gases expand and the piston is pushed down on the power stroke, as shown in view C. The exhaust stroke of the piston forces the burned gases out of the cylinder chamber, as shown in view D.

The operating procedures and operator maintenance routines for gasoline engines are essentially the same as those for diesel engines, except the fundamental difference in the ignition process.

Starting procedures for gasoline engines are much the same as those for diesels. There is, however, one important exception. Most gasoline engines are equipped with priming or choking devices to aid in starting a cold engine. Generally, these priming devices simply dump raw fuel into the cylinders; that is, the fuel is not thoroughly mixed with air or atomized before induction into the cylinders. Although such a rich mixture of fuel aids in achieving initial combustion, not all the fuel is burned. In other words, we have incomplete combustion. Prolonged or excessive choking during and after the start can, therefore, lead to carbon deposits being built up in the engine. For this reason, the operator should always use care and restraint in choking or priming the engine, both during and after the start.

Securing procedures for gasoline engines are also basically the same as those for diesels, although some gasoline engine installations may not permit circulation of lube oil and coolant after the engine has been stopped.

As you might expect, operator maintenance routines for gasoline engines differ from those for diesels because of the slight differences in design and construction of gasoline engines. In other words, gasoline engine maintenance and inspection schedules must provide for the inspection, adjustment, and maintenance of such items as carburetors, chokes, ignition coils and wiring, distributors, and spark plugs.

Safety

Whenever gasoline or diesel engines are secured for maintenance and inspection purposes, the operator should always guard against intentional or inadvertent starting of the engine by uninformed personnel. This rule applies to all types of prime movers, including electric motors. It also applies to maintenance and inspection operations being performed only on the driven equipment. Regardless of whether the work is being done on the prime mover itself or on the driven equipment alone, unintentional starting of the prime mover during the maintenance operation can result in serious damage to the machinery and serious injury to maintenance personnel. For this reason, prime mover controls must always have warning posters securely attached and plainly visible before the maintenance and inspection operation is begun. In most situations, it may be a good idea to completely disable the starting mechanism so that even if personnel fail to see or read the warning posters, the prime mover cannot be started.

During the maintenance operation, the operator must keep a strict accounting of all tools and parts. Tools, nuts and bolts, or any other material left adrift can foul a moving part and completely disable the machinery during subsequent operation. There is another reason for keeping a strict accounting of parts whenever components are disassembled. Parts that work together wear together. The various parts of valve assemblies, bearing assemblies, and so on, should, therefore, be carefully marked and grouped during disassembly and replaced in the same position from which they were removed. Otherwise, discrepancies in fitting and joining can result and reduce the mechanical efficiency of the moving parts. This can eventually lead to a breakdown.

When inspecting an engine or motor that is in operation, the operator should always be cautious while working near moving parts. Loose clothing, rags hanging from pockets, dangling key chains, and so forth, can easily become entangled with, or drawn into, moving parts, resulting in a serious accident.

Cleanliness

Engine maintenance and inspection require cleanliness. Dirt allowed to accumulate on and around an engine can find its way inside that engine. It may be carried into the engine with air, fuel, lube oil, or water, or it may be introduced by careless personnel. Dirt can cause sludge and scale deposits that impair circulation of fuel, oil, and water, and erode moving parts. Large accumulations of dirt on external surfaces can insulate the surface and reduce cooling.

Normally, there are specific instructions available locally concerning cleanliness precautions while handling fuel, lube oil, and so on. You must know and observe these precautions. Some fundamental cleanliness precautions follow.

- Never use waste or linty rags around fuel or lube oil containers, fuel inspection equipment, or carburetors.

- Keep fuel and lube oil handling equipment, such as measures, funnels, and containers, scrupulously clean and covered when not in use.

- Use clean, soft water in engine radiators and coolant systems to keep the engine water jackets free of sediment and use distilled water in topping off batteries.

- Keep engine air intake filters clean to maintain sufficient induction of air.

PUMPS

As a Utilitiesman, you will probably work with many types of pumps, large and small. Pumps are used to supply feedwater to boilers, to deliver fuel oil to oil-fired boilers, to circulate coolants and lubricants in internal combustion engines, to supply chemical feed in water purification systems, to lift water from cells and distribute it throughout a system, and to discharge sewage into settling tanks or mains.

The principles of pump operation, the principle of suction force, the types of valves used in pump operation, the different types of pumps, pump installation, and safety precautions that you, as a Utilitiesman, have to know for operating and maintaining pumps are discussed.

PRINCIPLES OF PUMP OPERATION

Pumps are used to move any substance that flows or can be made to flow. Most commonly, pumps are used to move water, oil, and other liquids. However, steam and other gases are also fluid and can be moved with pumps, as can molten metal, sludge, and mud.

A pump is a device that uses an external source of power to force fluid to move from one place to another. A pump develops no energy of its own; it merely transforms energy from the external source (steam turbine, electric motor) into mechanical kinetic energy, which is manifested by the motion of the fluid. This kinetic energy is then used to do work; for example, to raise liquid from one level to another, as when water is raised from a well; to transport liquid through a pipe, as when oil is moved through an oil pipeline; to move liquid against some resistance, as when water is pumped to a boiler under pressure; or to force liquid through a hydraulic system, against various resistances, for doing work at some point. Every pump has a POWER END, whether it be a steam turbine, a reciprocating steam engine, a steam jet, or some type of electric motor. Each pump also has a FLUID END, where the fluid enters (suction) and leaves (discharges) the pump.

The addition of energy to a liquid by a pump usually results in an increase in pressure, which is generally referred to as HEAD. In pump operation, you should know that there are four types of heads: net positive suction head, suction head, discharge head, and total discharge head. These terms are explained as follows:

- The NET POSITIVE SUCTION HEAD, or NPSH, is the suction pressure minus the vapor pressure expressed in feet of liquid at the pump suction.

- The SUCTION HEAD on a pump means the total pressure of the liquid entering the pump. In a deaerating feed tank operating under saturated conditions, the suction head of the feed booster pump equals the NPSH plus the auxiliary exhaust pressure.

- The DISCHARGE HEAD means the pressure of liquid leaving the pump or the level of liquid with respect to the level of the pump on the discharge side.

- The TOTAL DISCHARGE HEAD is the net difference between the suction head and the discharge head.

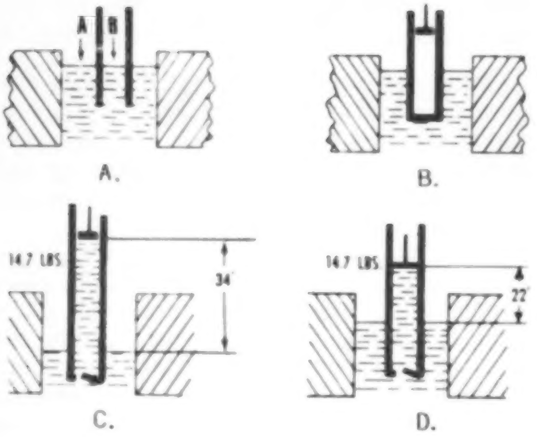

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Figure 5-6.—Diagrams illustrating the principles of suction force.

Suction head is usually expressed in feet of water if positive, and in inches of mercury if negative. When a pump operates below the level of a liquid, its suction end receives the liquid under a gravity flow. When the pump is located above the level of the liquid being pumped, the pump establishes a vacuum at the inlet to move the liquid into the pump. Atmospheric pressure, acting on the surface of the liquid, then provides the necessary pressure to move the liquid into the pump.

PRINCIPLE OF SUCTION FORCE

The principle of suction force, or "suction lift," as applied to reciprocating pumps is shown in figure 5-6. In diagram (A), the piston cylinder is open at both the top and bottom so the liquid level at A and B is the same. In diagram (B), the cylinder is closed at the bottom. A piston has been inserted and partly withdrawn, thus creating a partial vacuum. When the foot valve (check valve) at the bottom of the cylinder opens, diagram (C), as a result of the lower pressure in the cylinder, the liquid rises up into the cylinder, which causes the liquid level in the well to drop. Assuming the liquid is water and there is a perfect vacuum below the piston, atmospheric pressure pushes water up into the cylinder to a height of 34 feet, even though the piston may be raised higher than 34 feet.

You must understand that the preceding example is for the theoretical condition of a perfect vacuum. In practice, leakage between the piston and the cylinder, friction (fluid) in piping, and gases dissolved in the liquid, limit the suction lift of a pump to a height of approximately 22 feet, as shown in diagram (D) of figure 5-6.

When a pump is pumping certain liquids, such as hot water, oil, or gasoline, some of the liquid vaporizes because of the vacuum on the suction side of the pump. The pump may become vapor bound and reduce the possible suction lift; this is called "cavitation."

The suction force principle applies to other types of pumps, as well as to the reciprocating type, though to a lesser degree and in a different manner. The centrifugal, propeller, and rotary pumps all use suction force to a certain extent. Here a partial vacuum can be produced by the revolving mechanisms, instead of by the reciprocating plunger. Also, centrifugal pumps are not self-priming because they do not pump air. Their casing must be flooded before they can function. In the eductor (jet pump), flow is maintained by the suction force created by a jet of water, compressed air, or steam passing through a nozzle at high velocity. These principles are explained later in the chapter.

OPERATION OF VALVES USED WITH PUMPS

Every pump is equipped with devices for controlling the direction of flow, the volume of flow, and the operating pressure of the pump. A device that performs one or more of these control functions is called a VALVE.

A valve that permits liquid flow in only one direction is classified as a CHECK VALVE. In most cases, check valves open and close automatically; that is, they are kept closed or seated by spring tension or by the force of gravity until the liquid pressure above or below the valve overcomes the spring or gravity resistance and causes the valve to open. Check valves of this type are used with centrifugal pumps to automatically control the suction and discharge of liquid in the pump end at the proper time.

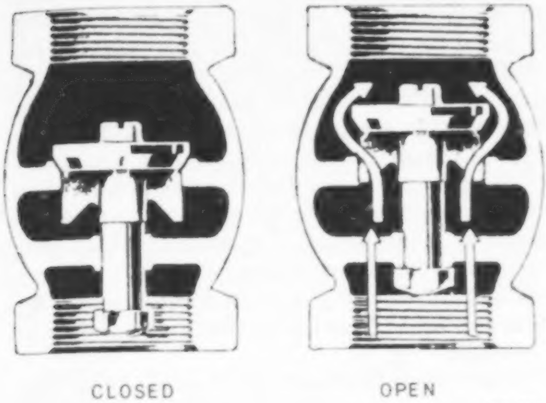

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Figure 5-7.—Vertical check valve.

Figure 5-7 shows a vertical check valve. In this case, the valve is kept seated by its own weight or the force of gravity. If desired, it could also be kept closed by a spring.

Another type of valve in pump systems is the STOP VALVE. Stop valves are usually opened or closed manually by means of a handwheel. They are used primarily to start or stop the flow of liquid through the pump during certain phases of operation. Thus, stop valves are often placed on suction and discharge lines, so the pump is isolated or sealed off from the rest of the liquid system. Figure 5-8 illustrates the operation of a gate valve. A gate valve is a type of stop valve. A gate or wedge is raised or lowered by turning the handwheel. Some types of stop valves are used for throttling purposes; that is, to regulate the flow of liquid. Gate valves, however, are never recommended for throttling service since the flow of liquid past the partially opened gate can rapidly corrode the gate face. Instead, the gate valve can be replaced with a tapered needle valve (another type of stop valve) which gradually opens or closes through the valve seat.

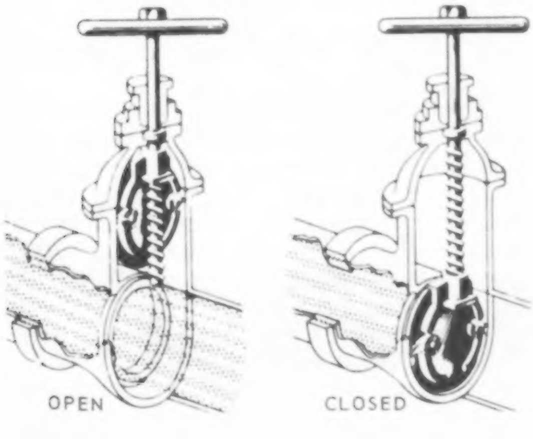

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Figure 5-8.—Operation of a gate valve.

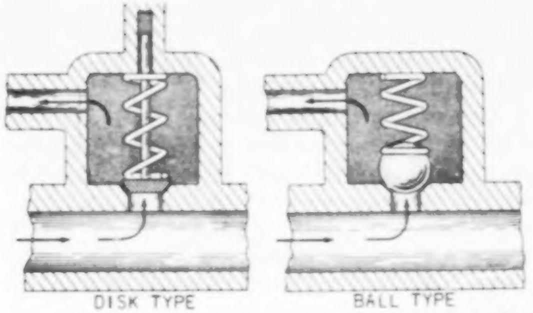

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Figure 5-9.—Relief valve.

A third type of valve generally found on most types of pumps is the RELIEF VALVE. As you can see from figure 5-9, most relief valves are similar in their design to check valves. These valves are designed to open when the liquid pressure in the pump becomes dangerously high. In most cases, the outlet of the relief valve is connected to a recirculating line that passes the excess liquid back to the suction side of the pump. Almost all pressure relief valves are fitted with an adjusting nut or screw that permits the spring tension to be regulated. In this way, the pressure at which the valve is opened can be varied.

TYPES OF PUMPS

Pumps may use a pushing, pulling, or throwing motion, or a combination of these movements. They are often named by the type of movement that causes the pumping action. There are five broad categories of pumps: rotary, reciprocating, centrifugal, airlift, and jet pumps.

Rotary Pumps

All rotary pumps use the principle of entrapment and displacement of fluid by rotating elements of various designs. These rotating parts, which may be gear teeth, screws, lobes, or vanes, trap the fluid at the suction inlet and remove it to the discharge outlet. Instead of "throwing" the water as in a centrifugal pump, a rotary pump traps it, pushes it around inside a closed casing, and discharges it in a continuous flow. Since rotary pumps move liquid by this method, they are often classified under the broad heading of positive displacement pumps.

Most rotary pumps have stuffing boxes provided at the rotor shafts to prevent excessive leakage at the shaft joint. In addition, various types of bearings can be fitted at the ends of the rotor shaft to minimize friction.

Generally, rotary pumps are self-priming; that is, the pump end need not be filled with liquid to initiate pumping action. Instead, the movement of the rotating elements creates a partial vacuum sufficient to lift or draw liquid into the pump and begin the pumping process. Note that self-priming and good suction lift are characteristics of the whole class of positive displacement pumps.

Rotary pumps are less expensive and considerably simpler in construction. In the utilities field, rotary pumps are used for pumping fuel oil in boiler houses, for pumping chemical feed in water purification systems, for priming larger pumps, and for special applications, such as emergency pumps at fire-fighting stations.

TYPES OF ROTARY PUMPS.—The types of rotary pumps are many and depend upon the kind of rotating element; however, in this section, two types of rotary pumps are discussed: the gear pump and the screw pump. Whatever form of rotating element is used, the basic principles of pump operation remain the same.

The GEAR PUMP is shown in figure 5-10. This type of pump uses two spur gears that rotate in opposite directions and mesh together at the center of the pump. One of the gears is coupled to the prime mover (usually an electric motor) and is called the driving gear. The other gear, which receives its motion by meshing with the driving gear, is called the driven gear. Note that liquid moves as the gear teeth rotate against the casing of the pump, thereby trapping the liquid and pushing it around to the discharge outlet. The meshing together of the two gears does not in itself move or pump liquid. The meshing of the gear teeth, in effect, forms a constant seal between the suction and discharge sides of the pump and thus prevents liquid from leaking back toward the suction inlet.

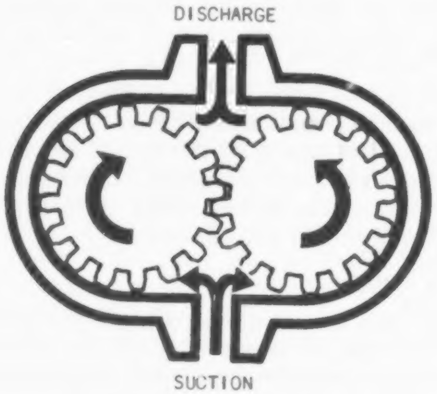

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Figure 5-10.—Gear-type rotary pump.

Very small clearances are permitted between the meshing gears and between the gear teeth and pump casing to avoid unnecessary friction and to allow the liquid being handled to act as a lubricant for the rotating parts. It should be evident, however, that when excessive clearances are allowed to develop between the gear teeth and casing or between the gears where they mesh, then the efficiency of the pump is considerably reduced. For this reason, rotary pumps are rarely, if ever, used to handle corrosive or abrasive liquids.

Of the several types of SCREW PUMPS, the main difference is the number of intermeshing screws and the pitch of the screws. Figure 5-11

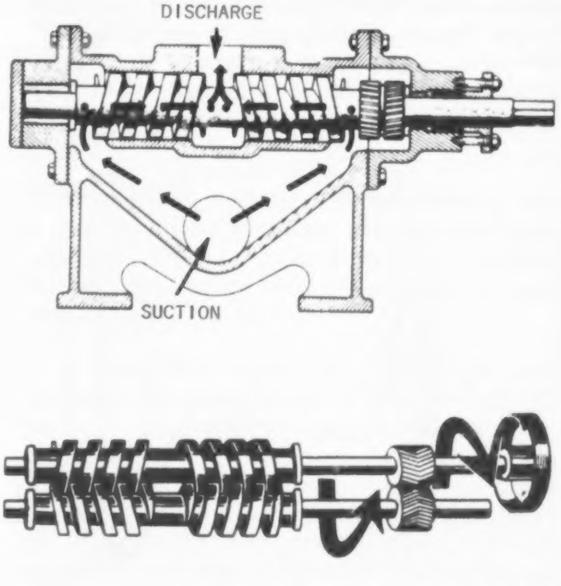

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Figure 5-11.—Positive displacement, double-screw, low-pitch pump.

shows a positive displacement, double-screw, low-pitch pump. Screw pumps are primarily used for pumping viscous fluids, such as JP-5 and diesel oil. Hydraulic systems use the screw-type pump as the pressure supply for the system. The pump may be either motor-driven or turbine-driven.

In the screw pump, liquid is trapped and forced through the pump by the action of rotating screws. As the rotor turns, the liquid flows in between the threads at the outer end of each pair of screws. The threads carry the liquid along within the housing to the center of the pump where it is discharged.

OPERATION AND MAINTENANCE OF ROTARY PUMPS.—The rotary pump is susceptible to hydraulicking. Therefore, the discharge stop valve must be in the open position before the pump is started. In addition, it is good operating practice to prime these pumps before operation whenever possible, particularly when the pump has been standing idle for any time. This is true in spite of the fact that rotary pumps are self-priming. Remember that the rotating elements of these pumps are lubricated by the liquid handled in the pump. When the pump end is filled with fluid before starting, unnecessary friction and wear of the rotating elements are avoided.

Rotary pump maintenance schedules stress that proper clearance be maintained between rotating parts. Thus, there should be periodic checks for slippage. In addition, when the pump is dismantled, the actual clearances should be carefully measured and compared with the manufacturer's specifications.

Reciprocating Pumps

A reciprocating pump moves water or other liquid by means of a plunger or piston that reciprocates (travels back and forth) inside a cylinder. Reciprocating pumps are positive displacement pumps; each stroke displaces a definite quantity of liquid, regardless of the resistance against which the pump is operating.

The standard way of designating the size of a reciprocating pump is by giving three dimensions in the following order:

1. The diameter of the steam piston
2. The diameter of the pump plunger
3. The length of the stroke

For example, a 12- by 11- by 18-inch-reciprocating pump has a steam piston 12 inches in diameter, a pump plunger 11 inches in diameter, and a stroke of 18 inches. The designation enables you to tell immediately whether the pump is a high-pressure or low-pressure pump.

The following discussion of reciprocating pumps is generally about direct-acting, simplex, double-acting, vertical pumps, since most reciprocating pumps used in the Navy are of these types.

TYPES OF RECIPROCATING PUMPS.—Reciprocating pumps are usually classified as follows:

- Direct acting or indirect acting
- Simplex (single) or duplex (double)
- Single acting or double acting
- High pressure or low pressure
- Vertical or horizontal

The pump shown in figure 5-12 is direct acting because the pump rod is a DIRECT

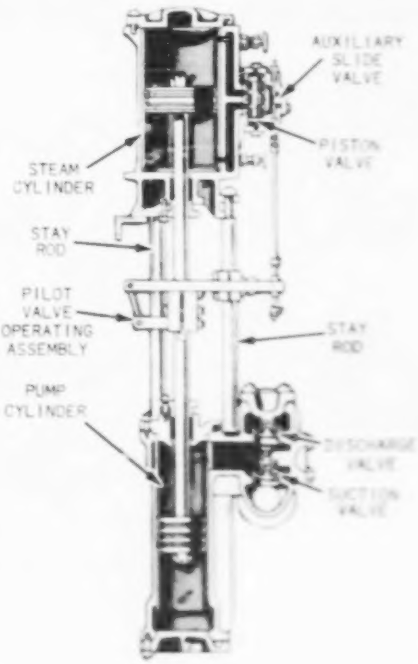

Figure 5-12.—Reciprocating pump.

extension of the piston rod and, therefore, the piston in the power end is DIRECTLY connected to the plunger in the liquid end. Most reciprocating pumps used in the Navy are direct acting. In an indirect-acting pump, there is some intermediate mechanism between the piston and pump plunger. The intermediate mechanism may be a lever or a cam. This arrangement can be used to change the relative length of strokes of piston and plunger or to vary the relative speed between piston and plunger. Or the pump may use a rotating crankshaft, such as a chemical proportioning pump in a distilling unit.

The diaphragm pump shown in figure 5-13 is a direct-acting reciprocating pump. It is commonly used by Utilitiesman to pump water from a ditch or sump.

Diaphragm pumps use a flexible diaphragm to move the liquid. The prime mover is usually a small gasoline engine with an eccentric connecting rod arrangement that converts rotary motion to reciprocating motion. On the suction stroke, the diaphragm is drawn upward into a concave configuration. This movement of the diaphragm results in a partial vacuum that causes the suction ball valve to unseat (and at the same time keeps the discharge ball valve seated) and to admit the liquid to the pump cylinder. On the discharge stroke, the diaphragm is pushed downward, forcing the trapped liquid out through the discharge valve. Thus, the liquid is made to move by the reciprocating motion of a flexible diaphragm.

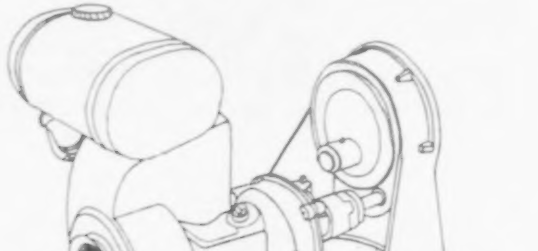

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Figure 5-13.—Portable diaphragm pump.

Since the diaphragm forms an almost perfect seal in the pump cylinder, between the liquid being pumped, and the rest of the pump and driving mechanism, there is some danger of liquid abrasion or corrosion of moving parts behind the diaphragm. For this reason, diaphragm pumps are especially well suited for pumping mud, slime, silt, and other wastes or heavy liquids containing debris, such as sticks, stones, or rags. Liquid strainers are, however, fitted at the suction inlet to prevent large objects from fouling the suction and discharge valves or from damaging the diaphragm.

You can use the diaphragm pump for dewatering trenches where sewer lines or waterlines are to be laid, or for repairing breaks in waterlines or sewer lines.

Two of the most popular types of diaphragm pumps are the mud hog (closed discharge) and the water hog (open discharge). The MUD HOG is for pumping heavy and thick liquids long distances away from the pump. The pump is fitted with discharge hose connections, and the ball valves and chambers are designed to prevent fouling by sticks, stones, rags, and so on.

The WATER HOG, on the other hand, is used for pumping thinner and less viscous liquids. It can, nevertheless, handle liquids containing sand, gravel, and mud. The discharge outlet from the water hog is open to permit free flow and increased discharge capacity. Thus, the liquid is discharged directly at the pump. A discharge hose, however, can be fitted to the pump if desired, but the efficiency is reduced somewhat. Both the mud hog and water hog can be of either the simplex or duplex type.

Because of the nature of the liquids handled by diaphragm pumps, operator inspection during pump operation becomes particularly important. Make frequent inspections of the suction inlet strainer to avoid accumulations of debris that reduce suction efficiency. Most diaphragm pump installations also permit easy access to the suction and discharge ball valves. The valve mechanisms can then be inspected frequently to detect scoring, fouling, and improper valve seating.

Because the diaphragm and ball check valves are subjected to the corrosive action of sand, gravel, and so on, they require frequent attention. Therefore, operator maintenance schedules stress a continuing program of inspection and cleaning of these parts. In most cases, it is not practical to repair damaged or worn diaphragms and valves. They should be replaced with new ones. So, keep an adequate supply of these parts readily available.

The reciprocating pump shown in figure 5-12 is called a single or simplex pump because it has only one liquid cylinder. Simplex pumps are either direct acting or indirect acting. A double or duplex pump is an assembly of two single pumps placed side by side on the same foundation; the two steam cylinders are cast in a single block, and the two liquid cylinders are cast in another block.

In a single-acting pump, the liquid is drawn into the liquid cylinder on the first or SUCTION STROKE and is forced out of the cylinder on the return or DISCHARGE STROKE. In a double-acting pump, each stroke serves both to draw in the liquid and to discharge the liquid. As one end of the cylinder is filled, the other end is emptied; on the return stroke, the end that was just emptied is filled and the end that was just filled is emptied.

The pump shown in figure 5-12 is double acting, as are most of the reciprocating pumps used in the Navy. (NOTE: Only one of two sets of valves is shown in figure 5-12.)

The pump, illustrated in figure 5-12, is designed to operate with a discharge pressure higher than the pressure of the steam operating the piston in the steam cylinder; in other words, it is a high-pressure pump. In a high-pressure pump the steam piston is larger in diameter than the plunger in the liquid cylinder. Since the area of the steam piston is greater than the area of the plunger in the liquid cylinder, the total force exerted by the steam against the steam piston is concentrated on the smaller working area of the plunger in the liquid cylinder; therefore, the pressure per square inch is greater in the liquid cylinder than in the steam cylinder. A high-pressure pump discharges a comparatively small volume of liquid against high pressure. A low-pressure pump, on the other hand, has a comparatively low discharge pressure but a larger volume of discharge. In a low-pressure pump, the steam piston is smaller than the plunger in the liquid cylinder.

Finally, the pump shown in figure 5-12 is classified as vertical because the steam piston and the pump plunger move up and down. Most reciprocating pumps in naval use are vertical; however, you may occasionally encounter a horizontal pump, where the piston moves back and forth instead of up and down.

OPERATION AND MAINTENANCE OF RECIPROCATING PUMPS.—The power end of a reciprocating pump consists of a bored cylinder in which the steam piston reciprocates. The steam cylinder is fitted with heads at each end; one head has an opening to accommodate the piston rod. Steam inlet and exhaust ports connect each end of the steam cylinder with the steam chest. Drain valves are installed in the steam cylinder so that water resulting from condensation can be drained off.

The admission and release of steam to and from each end of the steam cylinder are automatically timed by a valve operating assembly (fig. 5-14) that connects the pilot valve operating rod and the pump rod. As the crosshead arm (sometimes called the rocker arm) is moved up and down by the movement of the pump rod, the moving tappet slides up and down on the pilot valve rod. The tappet collars are adjusted so the pump makes the full-designed stroke.

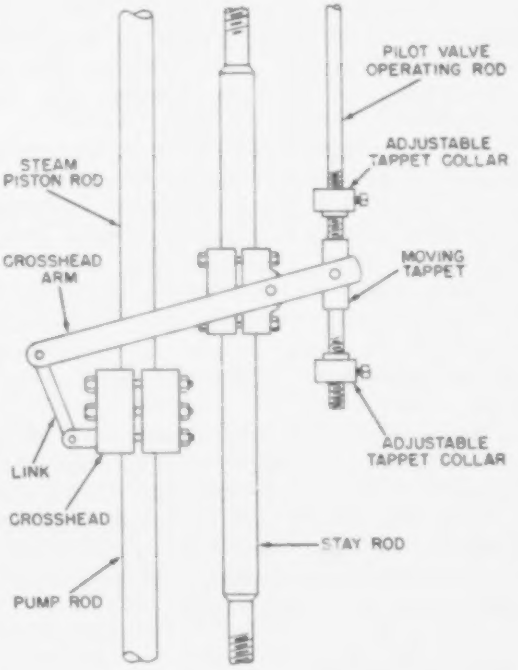

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Figure 5-14.—Valve operating assembly for reciprocating pump.

The piston-type valve gear, commonly used for automatic timing, consists of a piston-type slide valve and a pilot slide valve. The position of the pilot slide valve is controlled by the position of the main piston in the steam cylinder. At the completion of the downstroke of the pump, the crosshead arm moves the moving tappet against the upper adjustable tappet collar to actuate the pilot slide valve that admits steam to reposition the floating piston. The movement of the floating piston opens ports to admit steam to the underside of the piston in the steam cylinder and to exhaust the steam above the piston, thus causing the piston to move upward. Once the pump has completed the upstroke, the cycle repeats itself in reverse.

Reciprocating pumps are easy to operate and usually are very reliable units. They do, however, require routine maintenance and, upon occasion, some repair work. Consult the manufacturer's technical manual for details on the repair of a specific unit.

Before repairing or examining a pump, assemble the pertinent blueprints, drawings, and available data. These drawings and data furnish the required clearances, tools to be used, measurements, information on materials to be used, and other important data. In addition, you should have the complete history of the pump being repaired so you know what has been done, when repairs were last made, and what kind of trouble has been encountered before with this pump.

Whenever reciprocating pumps are opened for repairs, micrometer or caliper measurements should be taken of the main cylinders and the valve chest cylinders. These measurements are made on the fore and aft and athwartships (side to side) diameters at the top, middle, and bottom. The results should be recorded with accompanying remarks on a diagrammatic sketch showing the measurements obtained and the date they were made.

Remember that the steam end of a reciprocating pump should NOT be dismantled until a thorough check reveals that the water end is satisfactory. Most reciprocating pump troubles, however, result from fouled water cylinders, worn valves, or from faulty conditions in the pipe connections external to the pump.

Centrifugal Pumps

When a body, or a liquid, is made to revolve or whirl around a point, a force is created that impels the body or fluid to move outward from the center of rotation. This phenomenon is called CENTRIFUGAL FORCE. It is from this force that the centrifugal pump got its name.

The basic centrifugal pump has only one moving part: a wheel or impeller, that is connected to the drive shaft of a prime mover and rotates within the pump casing. The design or form of the impeller varies somewhat. However, whatever its form, the impeller is designed to impart a whirling or revolving motion to the liquid in the pump. When the impeller rotates at relatively high speeds, sufficient centrifugal force is developed to throw the liquid outward and away from the center of rotation. Thus, the liquid is sucked in at the center or eye of the impeller (center of rotation) and discharged at the outer rim of the impeller.

Note that by the time the liquid leaves the impeller, it has acquired considerable velocity. In this connection, a fundamental law of liquid physics states, in part, that as the velocity of a fluid increases, the pressure or pressure head of that fluid decreases. Therefore, the liquid discharge from the impeller has a high velocity but low pressure.

Before the liquid can be discharged from the pump, an INCREASE in pressure is necessary. In other words, the primary concern in practically all pumping systems is to maintain the discharge pressure so liquid can be distributed effectively throughout the system. In centrifugal pumps, a device is required to decrease the velocity of the impeller discharge and thereby increase the liquid pressure at the discharge outlet.

One method of increasing the discharge pressure of centrifugal pumps is by providing additional impellers. Pumps with only one impeller are SINGLE STAGE. Pumps with two or more impellers are MULTISTAGE. In multistage pumps, two or more impellers are placed on a common shaft (within the same pump housing), with the discharge of the first impeller being led into the suction of the next impeller, and so on. As the liquid passes from one stage to the next, additional pressure is imparted to it. In this fashion, the final discharge pressure of the pump can be increased considerably.

TYPES OF CENTRIFUGAL PUMPS.— Centrifugal pumps are also HORIZONTAL or VERTICAL, depending upon the position of the pump shaft. Generally, large, multistage, high-capacity pumps are horizontal. Most other pumps are vertical.

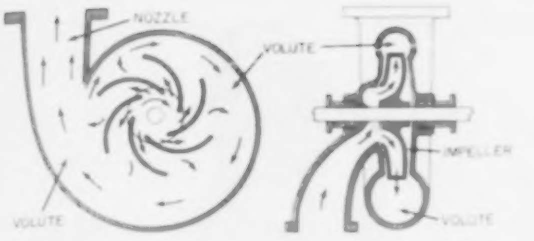

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Figure 5-15.—Simple volute pump.

The impellers used on centrifugal pumps may be SINGLE SUCTION or DOUBLE SUCTION. The single-suction impeller allows liquid to enter the eye from one direction only; the double-suction type allows liquid to enter the eye from two directions.

Impellers are CLOSED or OPEN. Closed impellers have side walls extending from the eye to the outer edge of the vane tips; open impellers do not have these side walls. Most centrifugal pumps in the Navy have closed impellers.

In the VOLUTE type of centrifugal pump, shown in figure 5-15, the impeller discharges into a volute or gradually widening channel in the pump casing. As the liquid passes into the expanding neck of the volute, its velocity is considerably diminished; and, with this decrease in velocity, the pressure increases.

Another variation is the DIFFUSER or VOLUTE TURBINE type of centrifugal pump, shown in figure 5-16. In this pump, the impeller discharges into stationary diffuser vanes surrounding the impeller. The diffuser vanes force a rather radical change in the direction of the impeller discharge, and this, in turn, slows down the discharge. In addition, the diffuser vanes form volutes of their own that further diminish the velocity of the discharge. Finally, the discharge from the diffuser vanes flows along the pump casing which, like the simple volute-type pump, is also in the form of a volute. Thus, the diffuser-type pump provides for a nearly complete decrease in velocity and consequently an increase in discharge pressure.

Certain types of centrifugal pumps are also used for pumping sewage. These types, however, do not use diffuser vanes, since the rapid change in direction of the impeller discharge can cause suspended matter in the liquid to come out of suspension and form deposits that corrode and foul moving parts.

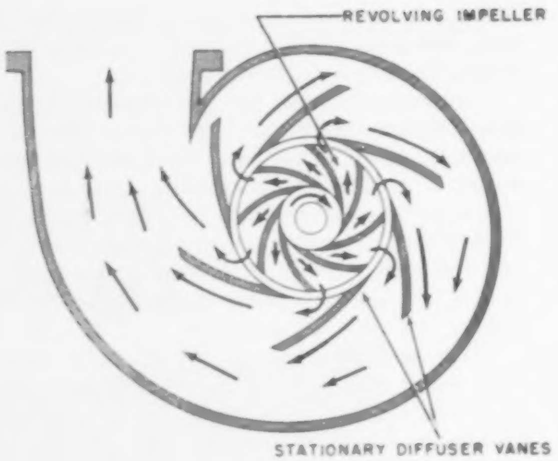

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Figure 5-16.—Diffuser-type centrifugal pump.

Other types of centrifugal pumps, known as turbine well pumps, are used to pump wells. To produce sufficient discharge pressure, provide these pumps with multistage impeller arrangements, contained in volutes referred to as bowls. To ensure satisfactory suction, set the impellers and bowls below the lowest drawdown or pumping level that the water in the well is expected to reach.

USES OF CENTRIFUGAL PUMPS.—The applications of centrifugal pumps are numerous. Several uses of centrifugal pumps are listed below. Pumps are generally used in buildings for (1) general water supply, including both overhead and pneumatic tank systems; (2) booster service; (3) domestic water supply; (4) fire protection; (5) circulating service; (6) sump drainage; and (7) sewage pumping.

In general water supply, where the pump takes off directly from the city pressure main or where there is no suction lift, a centrifugal pump can be used. Where there is a suction lift not over 15 feet, a centrifugal pump with an automatic primer or a reciprocating pump can be used.

In booster service, centrifugal pumps with intake pressures from the city main operate only to boost this pressure. They may run continuously or automatically. When the automatic type is not operating, the water flows by city pressure through the impellers.

For domestic water supply, the centrifugal pump is used in shallow wells (suction lift not over

22 feet), in deep wells (for greater depths than 22 feet), and in a complete pneumatic system, with electric motors or gasoline engines.

Fire pumps usually are the centrifugal type, either single or multistage. They may be driven by electricity, steam, or gasoline. Whatever the power supply, it must be permanent and, if steam, must have a constant minimum pressure of 50 pounds of steam. The pumps should agree with the specifications of the NFPA. Booster fire pumps have a low head to boost the pressure of the already available city supply.

Hot-water circulating pumps are centrifugal. They move water in a closed system and thus usually require only a low head, though the static pressure in the systems may be high. The pumps should be selected with attention to strength of casing, efficient stuffing box, freedom from air and vapor binding, and flexible mounting.

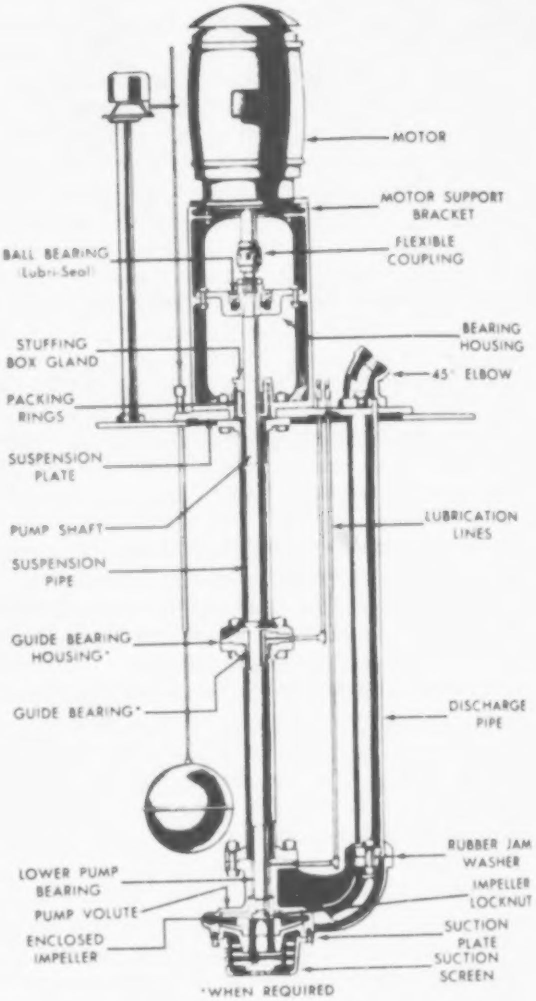
Sump pumps are not classified as sewage pumps; however, they can be used as such. They may be vertical or horizontal centrifugal. The vertical type usually has the impeller submerged and the motor mounted above the pit. Units are equipped with a float and an automatic switch operated by the float and are available in single or duplex type. (See fig. 5-17.)

Sewage ejectors for dry-pit installations have a connection on the suction end of the pump which is piped to a separate wet pit. (See fig. 5-18.)

With the sewage ejector, dry-basin type, equipment includes the pump with suction and discharge piping up to the floor plate, an electric motor, a steel ejector basin with separate sewage and pump compartments, a high-water alarm, an automatic alternator, float switches, a floor-mounted control panel, motor switches, automatic starters, an iron access ladder, and complete basin covers welded or riveted to the basin.

With the sewage ejector, wet-basin type (duplex wet basin nonclog sewage ejector), equipment includes the pump and fittings, electric motors, float switches, an automatic alternator, high-water alarm, motor switches, and automatic starters.

The centrifugal type of sewage pump has nonclogging impellers; it is either horizontal or vertical with a suction lift or is placed in a dry pit; and it has a float or diaphragm for automatic operation.

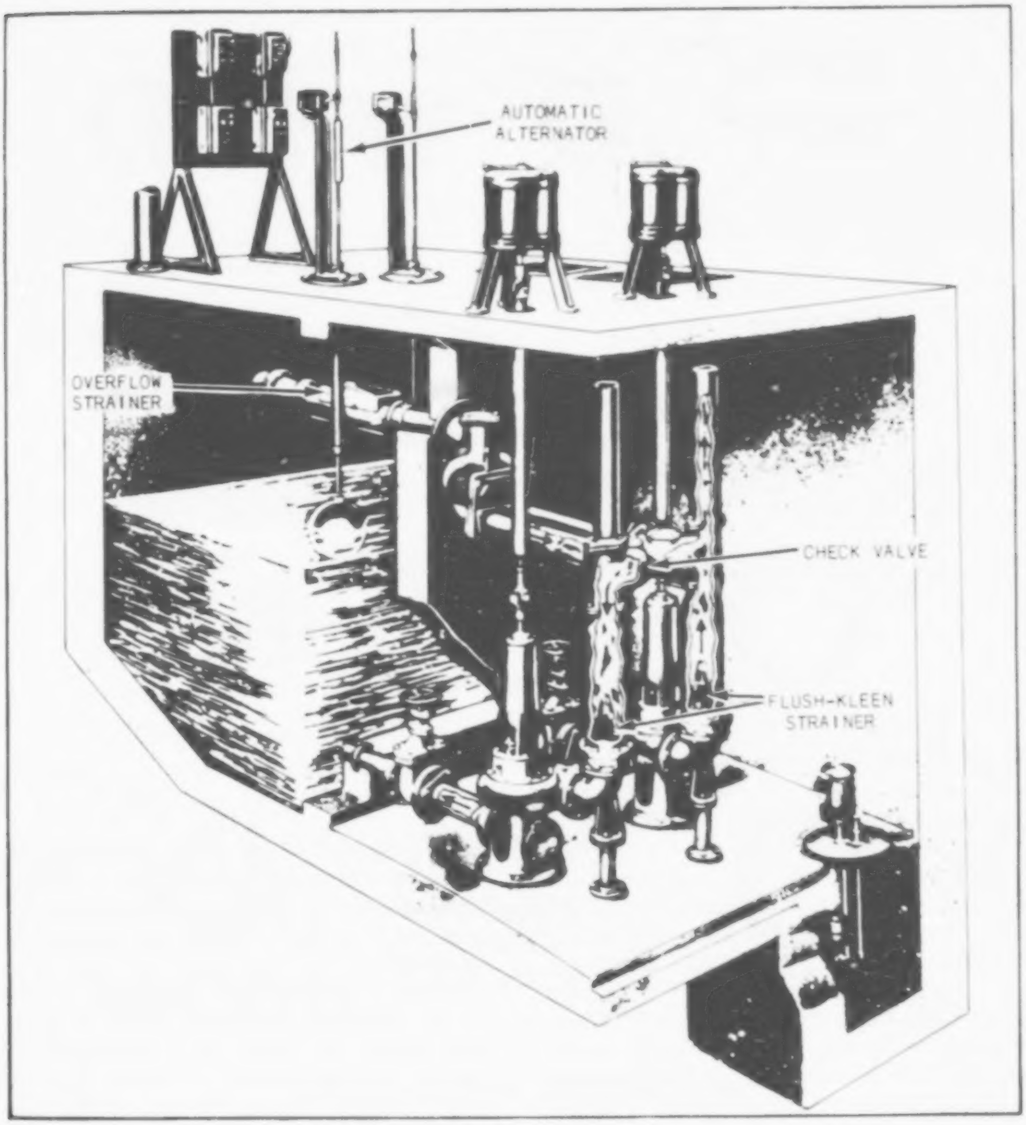

MOTOR
MOTOR SUPPORT BRACKET
BALL BEARING (Lubri-Seal)
FLEXIBLE COUPLING
BEARING HOUSING
STUFFING BOX GLAND
45° ELBOW
PACKING RINGS
SUSPENSION PLATE
LUBRICATION LINES
PUMP SHAFT
SUSPENSION PIPE
GUIDE BEARING HOUSING*
GUIDE BEARING*
DISCHARGE PIPE
RUBBER JAM WASHER
LOWER PUMP BEARING
IMPELLER LOCKNUT
PUMP VOLUTE
SUCTION PLATE
ENCLOSED IMPELLER
SUCTION SCREEN
*WHEN REQUIRED

54.432

Figure 5-17.—Vertical submerged-type centrifugal pump for sewage.

ADVANTAGES AND DISADVANTAGES OF CENTRIFUGAL PUMPS.—The advantages of centrifugal pumps include simplicity, compactness, weight saving, and adaptability to high-speed prime movers.

One disadvantage of centrifugal pumps is their relatively poor suction power. When the pump end is dry, the rotation of the impeller, even at high speeds, is simply not sufficient to lift liquid into the pump. The pump must, therefore, be primed before pumping can begin. For this reason, the suction lines and inlets of most centrifugal pumps are placed below the source level of the liquid pumped. The pump can then be primed by merely opening the suction stop valve and allowing the force of gravity to fill the pump

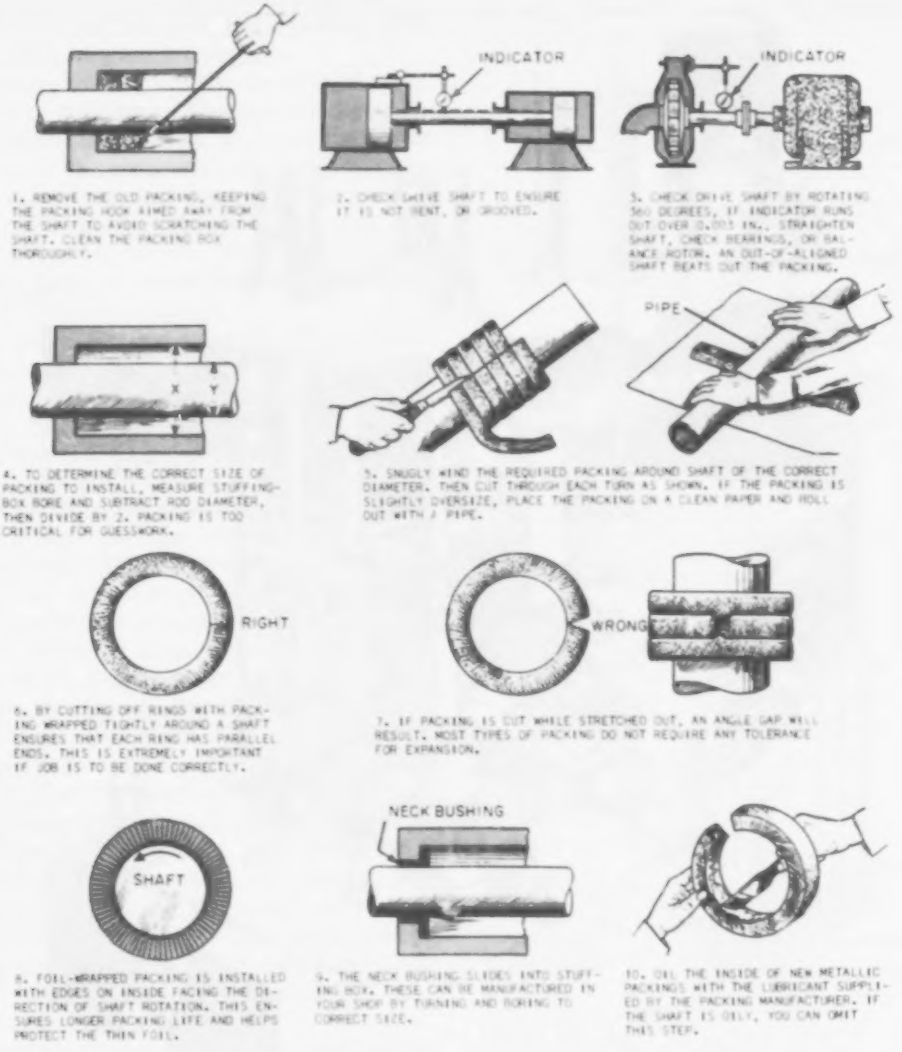


54.433

Figure 5-18.—Sewage ejector centrifugal pumps.

with liquid. The static pressure of the liquid above the pump also adds to the suction pressure developed by the pump while it is in operation.

Another disadvantage of centrifugal pumps is that they develop the phenomenon known as CAVITATION. Cavitation occurs when the velocity of a liquid increases to the point where the consequent pressure drop reaches the pressure of vaporization of the liquid. When this happens, vapor pockets, or bubbles, form in the liquid and then later collapse when subjected to higher pressure at some other point in the flow. The collapse of the vapor bubbles can take place with considerable force. This effect, coupled with the rather corrosive action of the vapor bubbles moving at high speed, can severely pit and corrode impeller surfaces and sometimes even the pump casing. In extreme instances, cavitation has caused structural failure of the impeller blades. Whenever cavitation occurs, it is frequently signaled by a



1. REMOVE THE OLD PACKING, KEEPING THE PACKING HOOK AIMED AWAY FROM THE SHAFT TO AVOID SCRATCHING THE SHAFT. CLEAN THE PACKING BOX THOROUGHLY.

2. CHECK DRIVE SHAFT TO ENSURE IT IS NOT BENT, OR GROOVED.

3. CHECK DRIVE SHAFT BY ROTATING 360 DEGREES, IF INDICATOR RUNS OUT OVER 0.003 IN., STRAIGHTEN SHAFT, CHECK BEARINGS, OR BALANCE ROTOR. AN OUT-OF-ALIGNED SHAFT BEATS OUT THE PACKING.

4. TO DETERMINE THE CORRECT SIZE OF PACKING TO INSTALL, MEASURE STUFFING-BOX BORE AND SUBTRACT ROD DIAMETER, THEN DIVIDE BY 2. PACKING IS TOO CRITICAL FOR GUESSWORK.

5. SNUGLY WIND THE REQUIRED PACKING AROUND SHAFT OF THE CORRECT DIAMETER. THEN CUT THROUGH EACH TURN AS SHOWN. IF THE PACKING IS SLIGHTLY OVERSIZE, PLACE THE PACKING ON A CLEAN PAPER AND ROLL OUT WITH A PIPE.

6. BY CUTTING OFF RINGS WITH PACKING WRAPPED TIGHTLY AROUND A SHAFT ENSURES THAT EACH RING HAS PARALLEL ENDS. THIS IS EXTREMELY IMPORTANT IF JOB IS TO BE DONE CORRECTLY.

7. IF PACKING IS CUT WHILE STRETCHED OUT, AN ANGLE GAP WILL RESULT. MOST TYPES OF PACKING DO NOT REQUIRE ANY TOLERANCE FOR EXPANSION.

8. FOIL-WRAPPED PACKING IS INSTALLED WITH EDGES ON INSIDE FACING THE DIRECTION OF SHAFT ROTATION. THIS ENSURES LONGER PACKING LIFE AND HELPS PROTECT THE THIN FOIL.

9. THE NECK BUSHING SLIDES INTO STUFFING BOX. THESE CAN BE MANUFACTURED IN YOUR SHOP BY TURNING AND BORING TO CORRECT SIZE.

10. OIL THE INSIDE OF NEW METALLIC PACKINGS WITH THE LUBRICANT SUPPLIED BY THE PACKING MANUFACTURER. IF THE SHAFT IS OILY, YOU CAN OMIT THIS STEP.

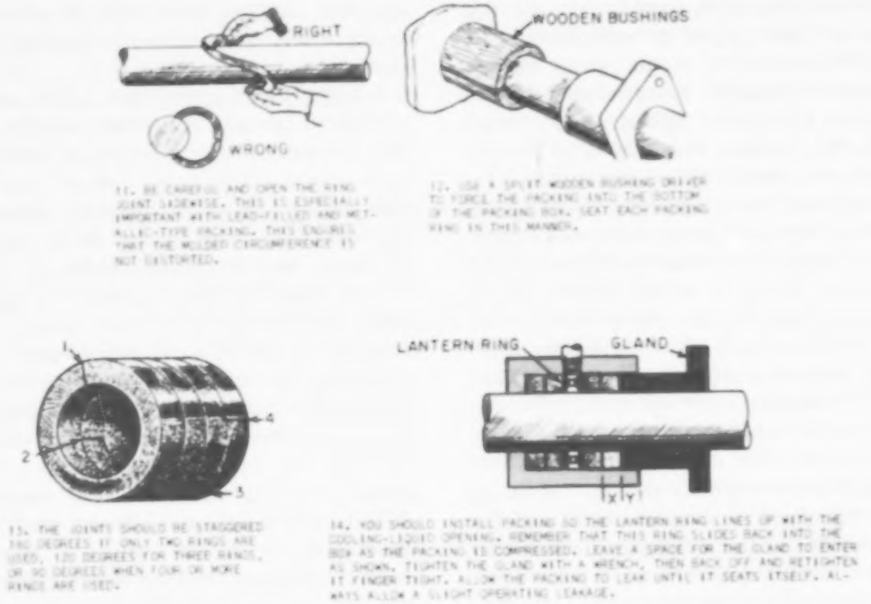
87.201

Figure 5-19.—Packing installation procedures.

clearly audible noise and vibration (caused by the violent collapse of vapor bubbles in the pump).

Several conditions can cause cavitation, not the least of which is improper design of the pump or pumping system. For example, if the suction pressure is abnormally low (caused perhaps by high suction lift or friction losses in the suction piping), the subsequent pressure drop across the impellers may be sufficient to reach the pressure of vaporization. A remedy might be to alter the pump design by installing larger piping to reduce friction loss or by installing a foot valve to reduce suction lift.

Cavitation can also be caused by improper operation of the pump. For instance, cavitation can occur when sudden and large demands for liquid are made upon the pump. As the liquid discharged from the pump is rapidly distributed and used downstream, a suction effect is created on the discharge side of the pump. Think of it as a pulling action on the discharge side which serves to increase the velocity of the liquid flowing through the pump. Thus, as the pressure head on the discharge decreases, the velocity of the liquid flowing across the impellers increases to the point where cavitation takes place. Perhaps the easiest way to avoid this condition is to regulate the liquid demand. If this is not possible, then increase the suction pressure by



11. BE CAREFUL AND OPEN THE RING JOINT SIDEWISE. THIS IS ESPECIALLY IMPORTANT WITH LEAD-FILLED AND METALLIC-TYPE PACKING. THIS ENSURES THAT THE MOLDED CIRCUMFERENCE IS NOT DISTORTED.

12. USE A SPLIT WOODEN BUSHING DRIVER TO FORCE THE PACKING INTO THE BOTTOM OF THE PACKING BOX. SEAT EACH PACKING RING IN THIS MANNER.

13. THE JOINTS SHOULD BE STAGGERED 180 DEGREES IF ONLY TWO RINGS ARE USED, 120 DEGREES FOR THREE RINGS, OR 90 DEGREES WHEN FOUR OR MORE RINGS ARE USED.

14. YOU SHOULD INSTALL PACKING SO THE LANTERN RING LINES UP WITH THE COOLING-LIQUID OPENING. REMEMBER THAT THIS RING SLIDES BACK INTO THE BOX AS THE PACKING IS COMPRESSED. LEAVE A SPACE FOR THE GLAND TO ENTER AS SHOWN. TIGHTEN THE GLAND WITH A WRENCH, THEN BACK OFF AND RETIGHTEN IT FINGER TIGHT. ALLOW THE PACKING TO LEAK UNTIL IT SEATS ITSELF. ALWAYS ALLOW A SLIGHT OPERATING LEAKAGE.

87.201

Figure 5-19.—Packing installation procedures—Continued.

some means to maintain pressure in the pump under these conditions.

OPERATION AND MAINTENANCE OF CENTRIFUGAL PUMPS.—The operating procedures and maintenance schedules for centrifugal pumps are generally similar to those of the other pumps we have discussed previously. Centrifugal pumps are also fitted with stuffing boxes and various types of bearings which, of course, require periodic maintenance and inspection. Again, refer to the manufacturer's instructions and locally prepared maintenance schedules for operating and maintenance procedures.

One operating practice is common to nearly all types of centrifugal pumps. Unlike positive displacement pumps, the discharge stop valve on centrifugal pumps must be CLOSED before starting the pump. This action allows the pump to work against the sealed discharge and builds up an effective pressure head before attempting to move and distribute the liquid downstream. After the pump is up to speed and the discharge valve is opened, the pump continues to maintain that pressure head unless the operating conditions are altered. Note that there is no danger of hydraulicking while the pump is run with the discharge closed. If, in fact, the centrifugal pump were to continue operation with the discharge sealed, it would simply build up toward its maximum discharge pressure and then begin to churn the liquid; that is, the discharge pressure would overcome the suction pressure and the liquid would continually slip back to the suction side of the pump. Nothing more would happen, except the pump would build up heat, since the liquid would not be able to carry away the heat generated by the moving parts.

There are several exceptions to the rule outlined above. For instance, when there are other pumps operating in parallel with the centrifugal pump, discharging into a common system, these pumps provide the centrifugal pump with an effective pressure head to start against. Another exception is the turbine well pump. This pump always has a pressure head to start against, provided by the weight or static pressure of the water above the impellers. Therefore, a turbine well pump can usually be started with the discharge valve in the open position. In the paragraphs below a few important aspects of pump operation and maintenance are discussed in detail.

One aspect of pump operation and maintenance is PACKING. Although this topic is included here under the general heading of centrifugal pumps, packing is used on many other types of pumps as well. Figure 5-19 shows packing installation procedures for centrifugal pumps.

Packing is a general term that refers to many different types of materials used to seal moving machinery joints (sliding pistons and piston rods, rotating shafts and valve stems, etc.) against leakage of steam or liquids. As such, packing can be thought of as a close-fitting bearing that must not only prevent leakage, but must also do this without causing excessive friction and undue wear of the moving part. Although most packing has definite lubricating qualities of its own, lubrication must normally be enhanced by permitting small amounts of liquid or steam to leak past or through the packing. If the pump is used for corrosive or abrasive fluids, then some other form of lubricant, such as grease or oil, must be fed to the packing through external means.

Packing usually takes the form of coils, rings, spirals, and the like. The packing is inserted into a stuffing box fitted around the sliding or rotating joint. The compression of the packing around the joint (and, therefore, the leakage) is controlled by hand-adjusted gland nuts.

The selection of the proper type of packing for a pump is important. There is no general purpose or all-purpose packing. The specific type of packing that must be used depends on several factors: whether the packing seals a rotating or sliding joint and the type of liquid handled by the pump. In any event, you do not have to select the packing. Locally prepared guides and/or manufacturer's instructions specify what type of packing material to use.

Upon receipt of the packing, note its condition and the use date stamped on the package to help you determine the shelf life of the packing. If a package has become unsealed, reseal it. Better yet, ensure the packing is used before its expiration date.

Packing requires frequent inspection and adjustment, particularly while the pump is in operation. The gland nuts must be adjusted with care so all the packing is compressed evenly and equally around the joint. If not, excessive and uneven wear of the packing can result, and the rotating or sliding shaft could become scored or grooved.

When a pump is first started, lubrication of the packing may be relatively poor. Because of initial friction, the packing may heat up and expand, thereby compressing itself around the joint and further reducing lubrication or leakage. Merely loosening or backing off the gland nuts is not always the best solution, since the liquid pressure in the pump can force the complete set of packing to move outward in the stuffing box. In this instance, the pump has to be shut down and the stuffing box allowed to cool. Several restarts may be necessary before the stuffing box runs cool.

Additional packing procedures are too extensive to be covered here. The primary purpose of this discussion of packing is to alert you to the importance of this pump component. It has been said that the proper inspection, adjustment, and upkeep of packing are the most abused aspects of pump operation and maintenance.

Another important aspect of pump operation and maintenance is the understanding of mechanical seals. Mechanical seals are rapidly replacing conventional packing as the means of controlling leakage on centrifugal pumps. Pumps fitted with mechanical seals eliminate excessive stuffing box leakage that results in pump and motor bearing failures and motor winding failures. Mechanical seals are ideal for pumps operating in closed systems, such as air-conditioning and chilled water systems.

One type of mechanical seal is shown in figure 5-20. Spring pressure keeps the rotating seal face snug against the stationary seal face. The rotating seal and all of the assembly below it are affixed to the pump shaft. The stationary seal face is held stationary by the seal gland and packing ring. A static seal is formed between the two seal faces and the sleeve. System pressure within the pump assists the spring in keeping the rotating seal face tight against the stationary seal face. The type of material used for the seal faces depends upon the service of the pump. Most water service pumps

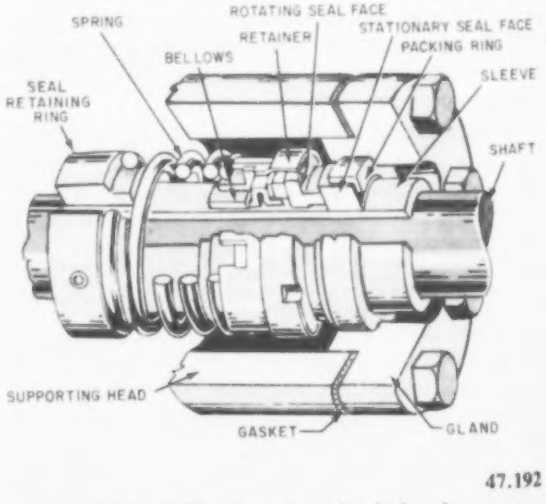


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Figure 5-20.—Type 1 mechanical seal.

use a carbon material for the seal faces. When the seals wear out, they are replaced. New seals should not be touched on the sealing face because body acid and grease cause the seal face to pit prematurely and deteriorate. Mechanical seals should be replaced whenever the seal is removed for any reason or whenever the leakage rate exceeds 5 drops per minute.

Mechanical seals are positioned on the shaft by means of stub or step sleeves. Mechanical seals should not be positioned by use of setscrews. Shaft sleeves are chamfered on outboard ends to provide ease of mechanical seal mounting. Mechanical seals ensure that positive liquid pressure is always supplied to the seal faces and that the liquid circulates well at the seal faces to minimize the deposit of foreign matter on the seal parts.

When a stuffing box is fitted with a lantern ring, be sure to replace the packing beyond the lantern ring at the bottom of the stuffing box, and be sure that the sealing water connection to the lantern ring is not blanked off by the packing. (See fig. 5-21.) Sleeves fitted at the packing on the pump shafts must always be tight. These sleeves are usually made secure by shrinking or keying them to the shaft. Be careful to ensure the water does not leak between the shaft and the shaft sleeves.

In some pumps, the shaft sleeve is pressed onto the shaft tightly by means of a hydraulic press, and the old sleeve must be machined off in a lathe before a new one can be installed. On other centrifugal pumps, the shaft sleeve is a snug slip-on fit, butted up against a shoulder on the shaft and held securely in place with a nut. On some small pumps, new sleeves can be installed by removing the water end casing, impeller, and old shaft sleeves. New sleeves are carried as repair parts, or they can be made in the machine shop. On large pumps, the sleeves are usually pressed on; these pumps must be disassembled and taken to the machine shop, a repair ship, or a Navy yard to have the old sleeve machined off and a new one pressed on.

Some sleeves are packed to prevent water leakage between the shaft and the sleeve, while some have O rings between the shaft and the abutting shoulder. For detailed information, consult the appropriate manufacturer's technical manual or applicable blueprints.

Shaft alignment must be checked frequently. If the shafts are out of line, the unit must be realigned to prevent shaft breakage and damage to bearings, pump casing wearing rings, and throat bushings. Shaft alignment should be checked with all piping in place.

The driving unit may be connected to the pump by a FLEXIBLE COUPLING. You should remember that flexible couplings (fig. 5-22) are intended to take care of only slight misalignment. Misalignment should never exceed the amount

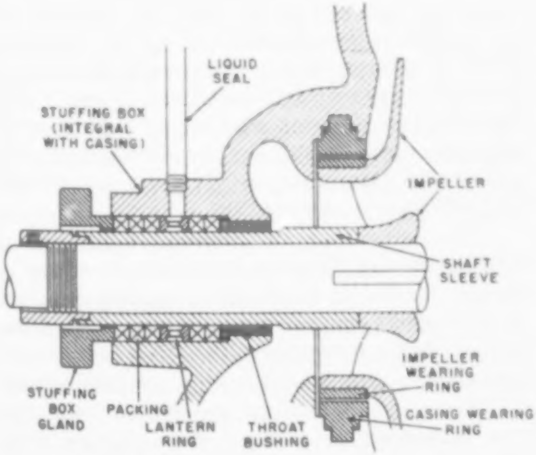

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Figure 5-21.—Stuffing box on centrifugal pump.

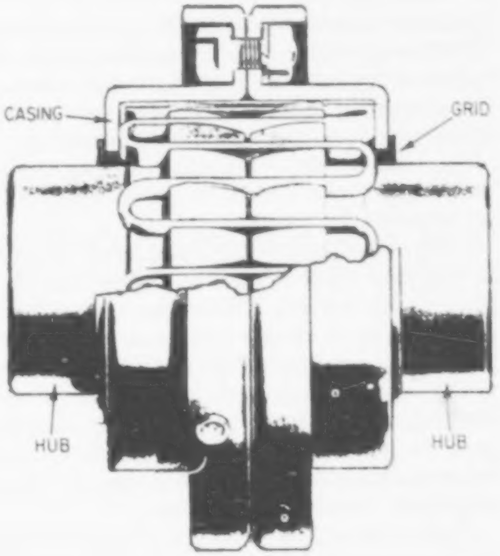

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Figure 5-22.—Grid-type flexible coupling.

specified by the pump manufacturer. When there is excessive misalignment, the coupling parts are punished severely, and pins, bushings, and bearings have to be frequently replaced.

The driving unit may be connected, or coupled, to the pump by a FLANGE COUPLING. Frequent realignment of the shaft may be necessary. Each pump shaft must be kept in proper alignment with the shaft of the driving unit. Misalignments are indicated by abnormal temperatures, abnormal noises, and worn bearings or bushings.

Wedges, or shims, are placed under the bases of both the driven and driving units to facilitate alignment when the machinery is installed. Jacking screws can also be used to level the units. When the pump or driving unit, or both need to be shifted sidewise to align the couplings, side brackets are welded in convenient spots on the foundations, and large setscrews are used to shift the units sidewise or endwise. When the wedges or other packings have been adjusted so the outside diameters and faces of the coupling flanges run true as they are manually revolved, the chocks should be fastened, the units should be securely bolted to the foundation, and the coupling flanges should be bolted together.

These ALIGNMENTS MUST BE CHECKED from time to time, and misalignments promptly corrected. There are three devices in use for checking the alignments: a 6-inch scale, a thickness gauge, and a dial indicator.

Shaft alignment should be checked whenever the pump is opened up and whenever a noticeable vibration is observed. When shafts are found out of line or inclined at an angle to each other, the unit should be aligned to avoid shaft breakages and renewal of bearings, pump casing wearing rings, and throat bushings. The appropriate technical manual should be consulted when you are aligning the pump.

In a centrifugal pump installation fitted with an internal water-lubricated bearing inside the pump casing (such as condensate pumps), an adequate supply of clean water must be supplied to the bearing for lubricating and cooling. Several of the following types of materials are used for internal water-lubricated bearings: laminated phenolic material grade FBM (fabric-based Bakelite or Micarta), high lead content bronze, graphited bronze, and lignum vitae.

The condition of all types of internal water-lubricated bearings should be checked frequently to guard against excessive wear which can result in misalignment and shaft failure.

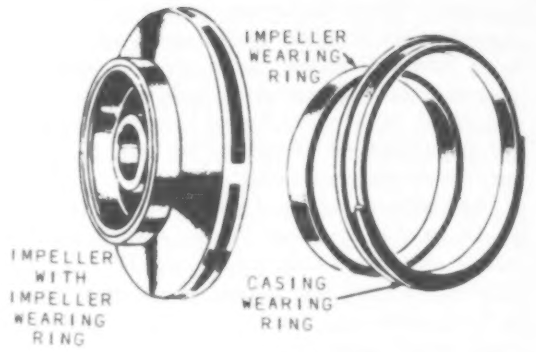

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Figure 5-23.—Impeller, impeller wearing ring, and casing wearing ring for a centrifugal pump.

As for oil-lubricated sleeve or shell-type bearings, the bearing clearances should be measured following procedures described for the pump, and clearances should be maintained within the limits specified in the manufacturer's technical manual.

The clearance between the impeller wearing ring and the casing wearing ring (fig. 5-23) must be maintained as shown in the manufacturer's plans. When clearances exceed the specified figures, the wearing rings must be replaced. This replacement requires the complete disassembly of the pump. Information on disassembly of the unit, dimensions of the wearing rings, and reassembly of the pump is in the manufacturer's technical manual. (Wearing rings are shown on the main feed pump shown in figure 5-24.)

In deciding whether the wearing rings need renewing, consider the capacity of the pump and the discharge pressure of the pump. On low-pressure pumps, the wearing ring diametrical clearance may be 0.015 to 0.030 inch more than the designed amount without any appreciable effect on the pump's capacity. For pumps with a discharge pressure up to 75 psi, a wear of 0.030 to 0.050 inch is permissible.

The percentage of capacity loss, with a 0.030-inch wearing ring clearance in excess of standard, may be large with a small pump, but comparatively small with a large pump. For high-pressure boiler feed pumps, the effect of increased wearing ring clearance is readily noticeable in the efficiency and maximum capacity of the pump. For high-pressure pumps, the wearing rings should be renewed when the clearance shown on the manufacturer's plans is exceeded by 100 percent. It is usually not necessary to renew wearing

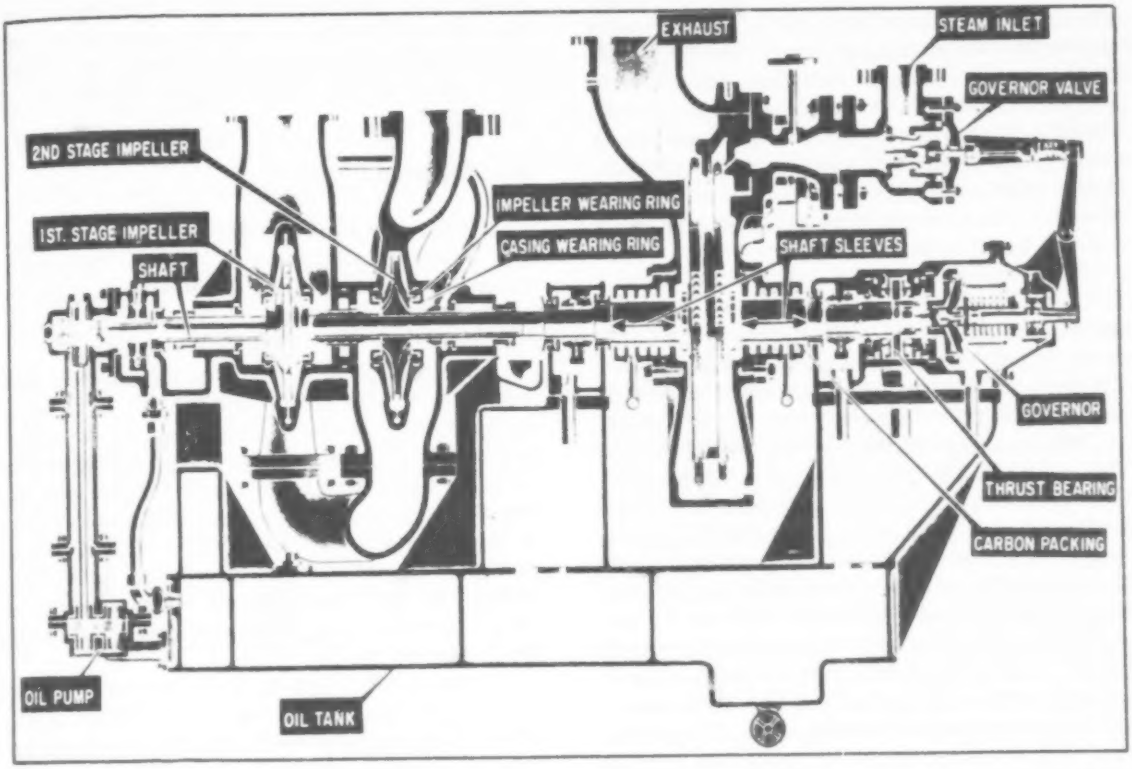

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Figure 5-24.—Two-stage centrifugal pump.

rings unless the wear is at least 0.015 inch. If a pump has to be disassembled because of some internal trouble, you should check the wearing rings for clearance. Measure the outside diameter of the impeller wearing ring with an outside micrometer and the inside diameter of the casing wearing ring with an inside micrometer; the difference between the two diameters is the wearing ring diametrical clearance. By checking the wearing ring clearance with the maximum allowable clearance, you can decide whether to renew the rings before reassembling the pump.

The amount of work in disassembling the pump, the length of time the pump can be out of commission without affecting the command, and whether a repair shop or other repair activity are needed are some of the factors in determining whether to renew wearing rings.

Wearing rings for most small pumps are carried aboard as part of the command's repair parts allowance. These may need only a slight amount of machining before they can be installed. For some pumps, such as main condensate and main feed booster pumps, spare rotors are carried. The new rotor can be installed and the old rotor sent to a repair activity for overhaul. Overhauling a rotor includes renewing the wearing rings, bearings, and the shaft sleeve.

OPERATING TROUBLES.—Some of the operating troubles with centrifugal pumps and probable causes are given in the paragraphs below.

If a centrifugal pump DOES NOT DELIVER ANY LIQUID, the trouble may be caused by (1) insufficient priming; (2) insufficient speed of the pump; (3) excessive discharge pressure, from a partially closed valve or other obstruction in the discharge line; (4) excessive suction lift; (5) clogged impeller passages; (6) the wrong direction of rotation; (7) clogged suction screen (if used); (8) ruptured (leaking) suction line; or (9) loss of suction pressure.

When a centrifugal pump delivers some liquid but operates at INSUFFICIENT CAPACITY, the trouble may be caused by (1) air leakage into the suction line; (2) air leakage into the stuffing boxes in pumps operating at less than atmospheric pressure; (3) insufficient speed of the pump; (4) excessive suction lift; (5) insufficient liquid on the suction side; (6) clogged impeller passages; (7) excessive discharge pressure; or (8) mechanical defects, such as worn wearing rings, impellers, stuffing box packing, or sleeves.

When a pump DOES NOT DEVELOP ENOUGH DISCHARGE PRESSURE, the trouble may be caused by (1) insufficient speed of the pump; (2) air or gas in the liquid being pumped; or (3) mechanical defects, such as worn wearing rings, impellers, stuffing box packing, or sleeves.

When a pump WORKS FOR A WHILE AND THEN FAILS TO DELIVER LIQUID, the trouble may be caused by (1) air leakage into the suction line, (2) air leakage in the stuffing boxes, (3) clogged water seal passages, (4) insufficient liquid on the suction side, or (5) excessive heat in the liquid being pumped.

When a motor-driven centrifugal pump TAKES TOO MUCH POWER, the trouble is normally indicated by overheating of the motor. The basic cause of the difficulty may be (1) operation of the pump at excess capacity and insufficient discharge pressure; (2) excessively high viscosity or specific gravity of the liquid being pumped; or (3) misalignment, a bent shaft, excessively tight stuffing box packing, worn wearing rings, or other mechanical defects.

VIBRATION of a centrifugal pump is often caused by (1) misalignment; (2) a bent shaft; (3) a clogged, eroded, or otherwise unbalanced impeller; or (4) lack of rigidity in the foundation. Insufficient suction pressure also causes vibration, as well as noisy operation and fluctuating discharge pressure, particularly in pumps that handle hot or volatile liquids.

When the pump fails to build up pressure, the discharge valve is open and the pump speed is increased, then use the following procedure:

1. Secure the pump.
2. Prime the pump and ensure that all the air is expelled through the air cocks on the pump casing.
3. Open all valves on the pump suction line.
4. Start the pump again. If the pump is electric driven, be sure the pump is rotating in the correct direction. If the discharge pressure is not normal when the pump is up to its proper speed, the suction line may be clogged, or an impeller broken. It is also possible that air is being drawn into the suction line or into the casing. If any of these conditions exist, stop the pump, try to find the source of the trouble, and correct it, if possible.

Air-lift Pumps

Air-lift pumps are used entirely in well pumping. Unlike the pumps studied earlier, the air-lift pump needs no moving or rotating mechanism to produce liquid movement. Instead, the pump uses compressed air to move or lift the liquid.

The air-lift pump operates on the principle that water mixed with air has less weight, or is more buoyant, than water without air. When compressed air is introduced, a mixture of water and air is formed in one leg of the U-shaped pipe, as shown in figure 5-25. The solid column of water in the other leg now has greater weight, or is exerting a greater static pressure, than the column containing air. Thus, the air-water column is forced upward until it discharges over the top of the U-shaped pipe.

In practice, of course, wells are not dug in a U-shape. Figure 5-26 shows a CENTRAL AIR-LIFT PUMP. Compressed air is led down an air pipe to a nozzle or foot piece submerged well below the water level. Notice that the foot piece

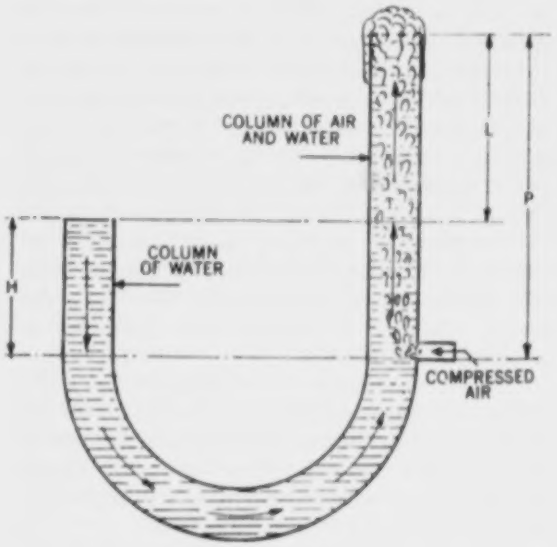

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Figure 5-25.—Principle of an air-lift pump.

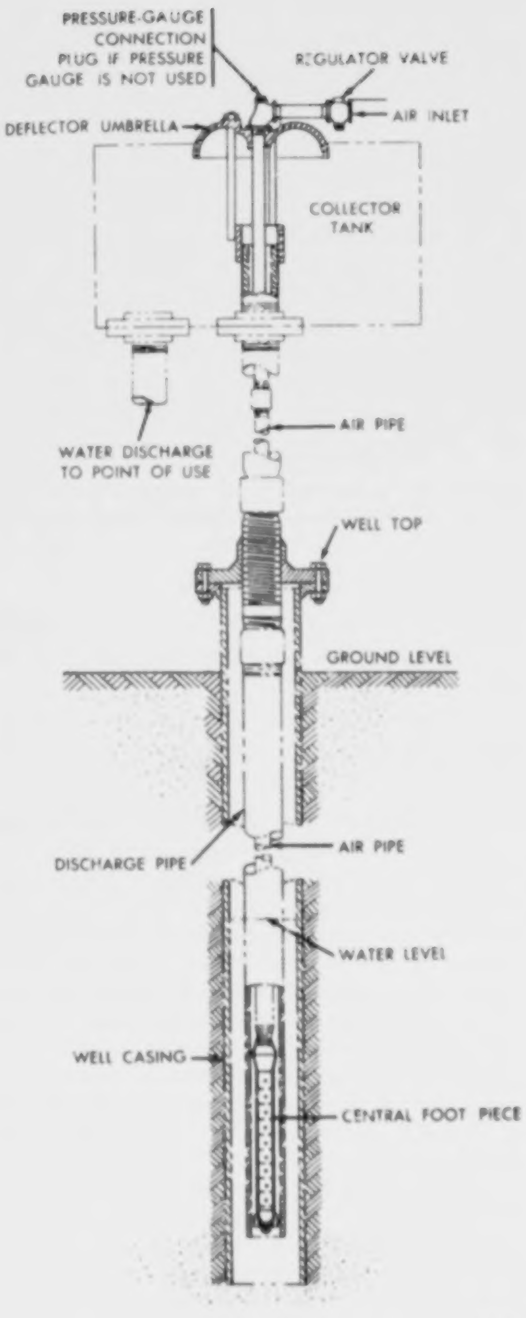

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Figure 5-26.—Central air-lift pump.

is suspended within a discharge pipe which, in turn, is contained within the well casing. Notice that the discharge pipe is open at the bottom, directly beneath the foot piece. When compressed air is discharged through the foot piece, a column or mixture of air is formed, above the foot piece, in the discharge pipe. The solid column of water in the well casing, resting high above the foot piece and discharge pipe inlet, now has greater weight or static pressure. This effect forces the air-water mixture upward in the discharge pipe where it is vented to the atmosphere through an open discharge outlet. In effect, the flow of water has a U-shape—down the well casing, around the foot piece, and up the discharge pipe. The air-water discharge then strikes a separator or deflector which relieves the water of air bubbles and entrained air vapor. The discharge then settles in a collector tank.

The air-lift pump can deliver considerable quantities of water in the manner just described. The discharge pressure at which it is delivered, however, is relatively low. So, air-lift pumps cannot be used to discharge directly into a water distribution system; that is, they do not develop sufficient pressure to distribute water horizontally above the ground for any appreciable distance. Instead, the discharge is collected at the well for ground storage.

The capacity of the air-lift pump depends largely on the percentage of submergency of the foot piece; that is, the greater the submergence of the foot piece below the water level in the discharge pipe, the greater the volume (column) of water the pump can deliver per unit of time. However, the deeper the foot piece is submerged, the greater the compressed air pressure must be to lift the column of water. In other words, a higher column of water (in the discharge pipe) above the foot piece exerts a greater weight or pressure at the foot piece. The greater the static water pressure at the foot piece, the greater the air pressure must be to infuse air with the water.

It is also true that starting air pressure is always greater than working air pressure. When the pump is started, the static (at rest) level of water is drawn down somewhat to a pumping or working level. In effect, the column of water above the foot piece is decreased or lowered, and this, in turn, decreases the air pressure required to infuse the water with air. In wells where the drawdown is rather large, the pump is sometimes equipped with an auxiliary air compressor, connected in series with the main compressor, for starting. Once the pump has been started and the

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pumping level reached, the auxiliary compressor is no longer required and is secured.

Air-lift pumps have a low discharge pressure and require more depth so the foot piece can submerge deep enough. Moreover, the entrained oxygen in air-lifted water tends to make it more corrosive. In spite of these drawbacks, air-lift pumps have several advantages, especially their simplicity of construction and lack of maintenance problems. Particularly useful in emergencies for deep well pumping, air-lift pumps can be used to pump crooked wells and wells with sand and other impurities. They can also pump hot-water wells with ease.

In air-lift pump operation, compressed air has to be regulated correctly. The amount of compressed air should be the minimum needed to produce a continuous flow of water. Too little air results in water being discharged in spurts, or not at all. Too much air causes an increase in the volume of discharge but at lower discharge pressure. If air is increased still further, discharge volume begins to decrease.

The air-lift pump is so simple in design that nearly all operating and maintenance inspections and procedures relate to the air compressor, which is described later.

Jet Pumps

Pumps that use the rapid flow of a fluid to entrain another fluid and thereby move it from one place to another are jet pumps. A jet pump contains no moving parts.

Jet pumps are EJECTORS that use a jet of steam to entrain air, water, or other fluid, and EDUCTORS that use a flow of water to entrain and thereby pump water. The basic principles of operation of these two devices are identical.

The basic principle of operation of a simple jet pump of the ejector type is shown in figure 5-27. Steam under pressure enters chamber C through pipe A, which is fitted with a nozzle, B. As the steam flows through the nozzle, the velocity of the steam is increased. The fluid in the chamber at point F, in front of the nozzle, is driven out of the pump through the discharge line, E, by the force of the steam jet. The size of the discharge line increases gradually beyond the chamber to decrease the velocity of the discharge and thereby transform some of the velocity head into pressure head. As the steam jet forces some of the fluid from the chamber into the discharge line, pressure in the chamber is lowered and the pressure on the surface of the supply fluid forces fluid up through the inlet, D, into the chamber and out through the discharge line. Thus the pumping action is established.

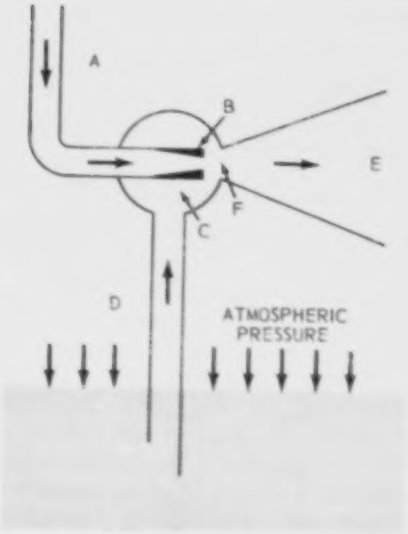

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Figure 5-27.—Principle of operation of an ejector-type jet pump.

INSTALLATION OF PUMPS

As a Utilitiesman, you will be installing prime movers, pumps, and air compressors. The secret of success in operating prime movers, pumps, and air compressors is their proper installation. That puts the success of their operation directly in your hands. If you do your job right and the equipment is properly installed, it should perform satisfactorily for a long time. Of course, proper care and maintenance are also essential for continued efficient operation. However, even with the most perfect care and maintenance, you will find it difficult or impossible to overcome faulty installation.

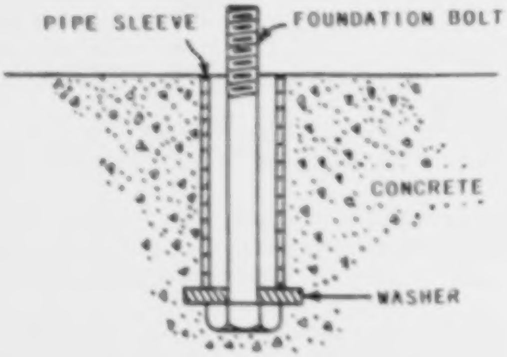
Since the procedures for installing prime movers, pumps, and air compressors are almost the same, only the basic steps of pump installation are discussed in this chapter. Remember that pumps, especially the centrifugal type, are built in many designs and for different purposes. Study the manufacturer's instruction manual for the equipment you are installing. Where specific directions or requirements are furnished, follow them.

When you receive a pump unit from supply, there are a few points to check. First, ensure it is the correct pump for the job by checking the nameplate data against that of the bill of material. Next, check the unit to ensure there are no missing or loose parts. If the unit has a preservative covering (exterior or interior), make certain it is removed before being installed.

When pumps are to be installed, the locations usually are determined in advance by higher authority and indicated on blueprints or sketches. However, you may have to decide where to put a pump. In most cases, place the pump as close as possible to the source of supply of water or other liquid so the suction pipe is short and direct and the suction lift is comparatively low. With high temperature liquids, a suction head is necessary. Place the pump where it can be readily inspected during operation, and see that headroom (a trap or ceiling opening) is there for the use of a crane, hoist, or tackle. If possible, select a dry place to protect the pump from the weather.

The foundation of a pump must be strong enough to absorb vibration and also to serve as a rigid support for the pump baseplate. A concrete foundation or a solid base is best.

Foundation J-bolts are embedded in the concrete foundation according to a blueprint or a template. The bolts should be longer than needed (3/4 to 1 inch) to allow for shimming up the pump to make it level and for grouting under the pump base. A pipe sleeve, about 2 1/2 times the diameter of the bolt, allows for final positioning. If the bolt shown in figure 5-28 were 1 inch in diameter, a 2 1/2-inch pipe sleeve should be used.

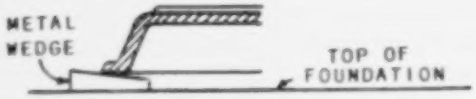


54.400

Figure 5-28.—Pipe sleeve and foundation bolt.

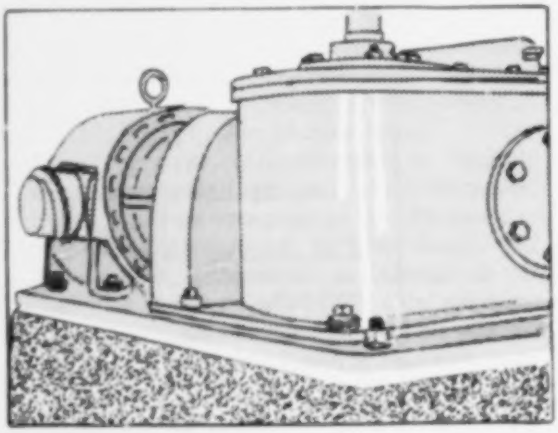
A small pump is normally aligned and the two major parts bolted together before leaving the factory. The parts normally do not require alignment after the pump has been set on the foundation. Be careful that you do not spring them out of alignment. Level the pump properly and secure it to the foundation. In setting the pump, you need a spirit level; place the level on the machined surfaces in two directions. To level, you may have to remove the top casing or bearing cover. If a large pump is shipped in sections, you have to align the water ends with the power ends after they have been placed on the foundation.

In leveling a pump unit, first use small metal wedges (fig. 5-29) and then place metal blocks and shims close to the foundation bolts. In each case, space the supports directly under the part carrying the most weight and close enough to give uniform support. Leave a gap of about 3/4 to 1 inch between the baseplate and the foundation for grouting with cement. (Grout is a mixture of cement, sand, and water, making up a thin mortar.) Figure 5-30 shows a baseplate of a pump unit grouted to the foundation.



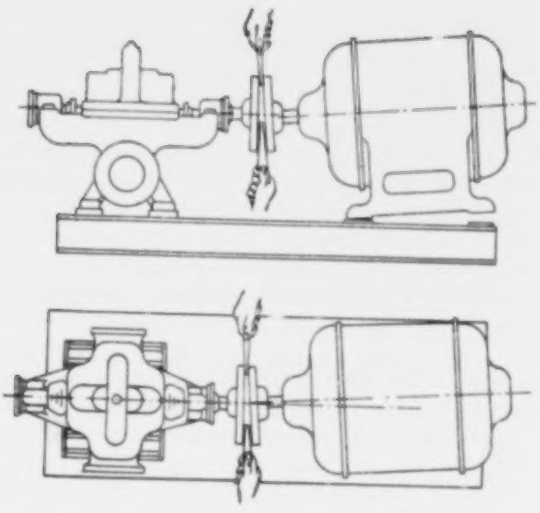
54.401

Figure 5-29.—Wedging a baseplate.



54.402

Figure 5-30.—Baseplate of a pump unit grouted to the foundation.



54.403

Figure 5-31.—Making angular alignment.

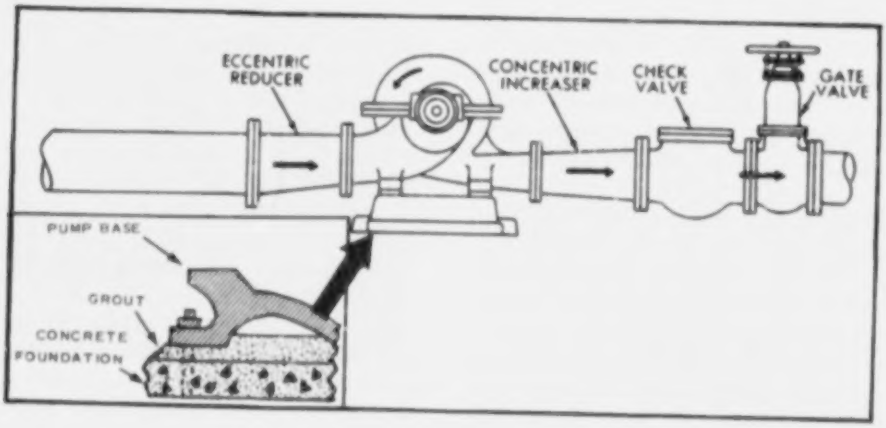
Adjust the supports or wedges until the shafts of the pump and the driver are level. By means of a level, check the coupling faces and suction and discharge flanges to see that they are plumb and level. Correct the positions by adjusting the supports or wedges as required.

Besides checking for parallel alignment, check the angular alignment between the pump shaft and the drive shaft. Insert a taper gauge or feeler at four points between the coupling faces, as shown in figure 5-31. The points should be spaced at 90° intervals around the coupling. When the measurements are all alike and the coupling faces are the same distance apart at the four points, the unit is in angular alignment. Correct any misalignment by adjusting the wedges or shims under the baseplate. Remember that an adjustment in one direction can disturb adjustments in another direction.

A great many of the pumps used by the Navy are centrifugal pumps. Figure 5-32 shows a typical installation of a centrifugal pump. There are two types of assembly in which centrifugal pumps are delivered.

One group has the pump and driver mounted on a common baseplate at the factory. The other group has only the pump mounted at the factory, so the driver must be positioned at the place of installation. In the former group, factory alignment may not have been maintained, as all baseplates are somewhat flexible. Therefore, you must realign the unit after it has been leveled on the foundation. To do this, first disconnect the coupling halves. Then follow the same alignment steps that have just been given. After completing these steps, reconnect the coupling and check it again for parallel and angular alignment.

To install a centrifugal pump of the second group, you have a little extra work. After you have placed the baseplate with the pump on the foundation, you level, align, and bolt it. Next, place the driver on the baseplate according to the blueprints. Adjust the position of the driver and shim it up until the pump and driver half couplings are aligned. Then bolt it securely and proceed as in the other installation.



23.18

Figure 5-32.—Typical installation of a centrifugal pump.

After you have correctly aligned the pump, tighten the foundation bolts evenly, but not too firmly. Then completely fill the baseplate with grout. Try to grout the leveling pieces, shims, or wedges in place. Foundation bolts should not be fully tightened until the grout has hardened, usually about 48 hours after pouring.

After the grout has set and the foundation bolts have been properly tightened, the pump should be checked again for parallel and angular alignment.

You are now ready to connect the piping. The pipes must line up naturally. Do not force them into place as this could draw the pump out of alignment. The pipes should also be supported independently, so they do not put any strain on the pump. One or more of these supports should be as near the pump as possible.

The size of the suction or discharge pipe leaving the pump is sometimes increased to reduce the loss of head from friction in the piping. Unnecessary bends should be eliminated from the piping to prevent loss of head. Eccentric reducers, as shown in figure 5-32, are usually recommended in the suction line to prevent the formation of air pockets. Whenever possible, bends should be made with a long radius. To remove the pump as easily as possible, use flanged fittings or unions in all connecting lines close to the pump.

After the piping has been connected, check the pump alignment again. Reconnect the coupling halves and start the pump. Let it warm up thoroughly and operate under normal conditions for a short time. Shut it down and immediately check for alignment of the couplings. All alignment checks must be made both with the coupling halves disconnected and again after they are connected.

Check alignment in all directions after making any adjustment. You may have to readjust the alignment slightly from time to time while the unit and foundation are new.

SAFETY PRECAUTIONS FOR PUMPS AND PRIME MOVERS

In working with pumps and their prime movers, be careful to avoid injury to anyone. Here are some safety precautions for you.

- Make sure that all suction and discharge valves are closed and tagged, as appropriate, before operating or beginning work with pumps.

- Inspect for security of connections, particularly in the fuel system of a prime mover.

- Ensure the ignition switch is in the OFF position before making operational checks or attempting repairs.

- Disengage the clutch (where provided) between the prime mover and the pump.

- See that exhaust fumes are piped outside when the pumps are to be operated in an enclosed area.

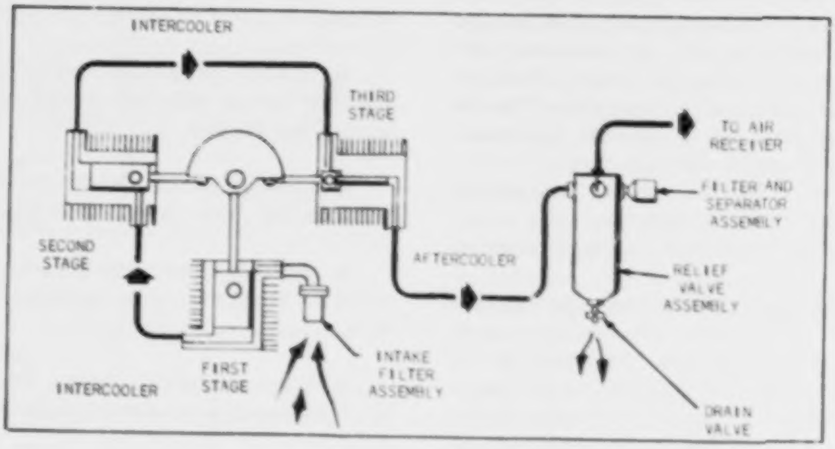
- Stop operations before adding fuels or lubricants to either the prime mover or the pump.

AIR COMPRESSORS

Air compressors are devices or machines that compress air. In compression, air at a normal atmospheric temperature is taken in and squeezed or pressed by a moving element within a confined space. The volume of air is thus reduced, but the pressure, or force, the volume of air exerts has increased considerably. Thus, the air develops energy or power that can be put to some useful purpose in other machines. The compressed air need not be put to work immediately, but can be stored in tanks to preserve and maintain its pressure.

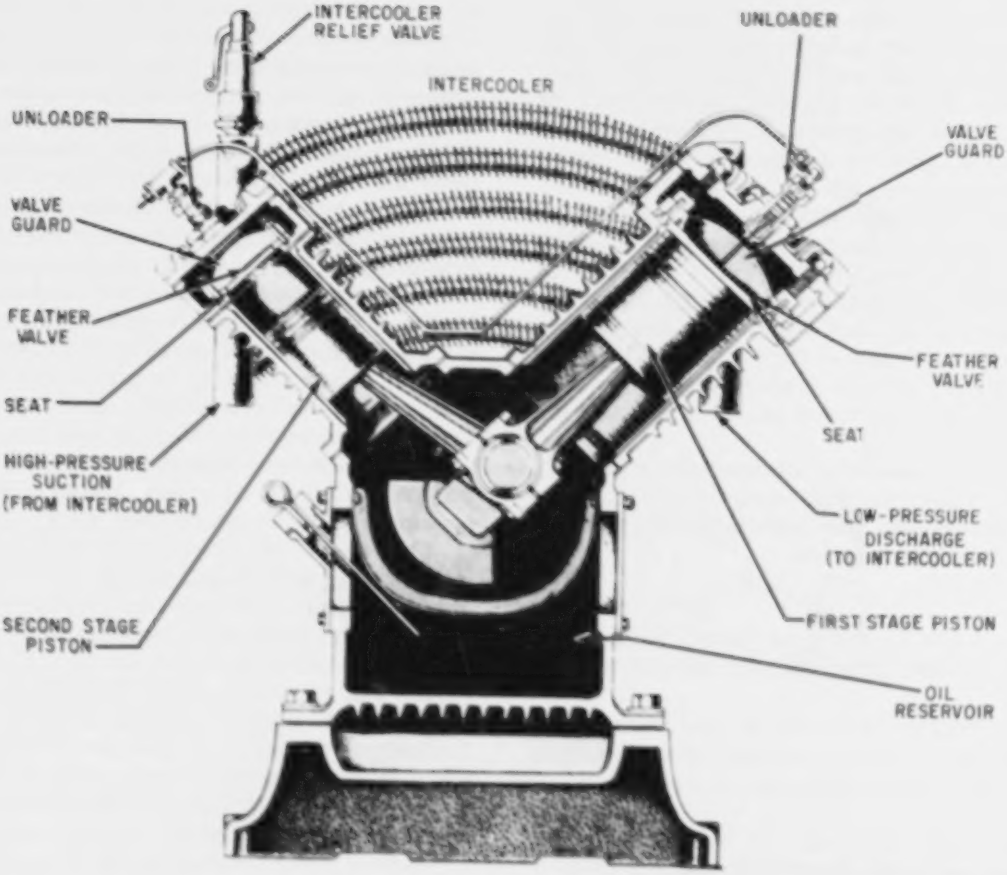
Compressed air can be taken from storage bottles or flasks and used to start diesel engines; that is, the compressed air is introduced into the diesel cylinders where, by its pressure, it forces the pistons to reciprocate until ignition temperature is reached. We have seen how compressed air forces water to rise in wells. Air compressors also drive, or power, a wide variety of pneumatic tools in construction work.

The types of air compressors include reciprocating, centrifugal, and rotary. However, only reciprocating compressors are discussed in the following paragraphs. In basic design and function, these compressors are similar to the pumps with the same names. In fact, air compressors are sometimes referred to as air pumps. Rather than discharging liquid at relatively high pressure, air compressors discharge air (which is considered a fluid) at high pressure. Like pumps, compressors require some external source of mechanical power to do this work. Prime movers for air compressors may be electric motors, internal combustion engines, steam turbines, and


INTERCOOLER
THIRD STAGE
TO AIR RECEIVER
FILTER AND SEPARATOR ASSEMBLY
SECOND STAGE
AFTERCOOLER
RELIEF VALVE ASSEMBLY
INTAKE FILTER ASSEMBLY
INTERCOOLER
FIRST STAGE
DRAIN VALVE

54.199

Figure 5-33.—Air compressor assembly.


INTERCOOLER RELIEF VALVE
UNLOADER
INTERCOOLER
UNLOADER
VALVE GUARD
VALVE GUARD
FEATHER VALVE
SEAT
HIGH-PRESSURE SUCTION (FROM INTERCOOLER)
SECOND STAGE PISTON
FEATHER VALVE
SEAT
LOW-PRESSURE DISCHARGE (TO INTERCOOLER)
FIRST STAGE PISTON
OIL RESERVOIR

47.152

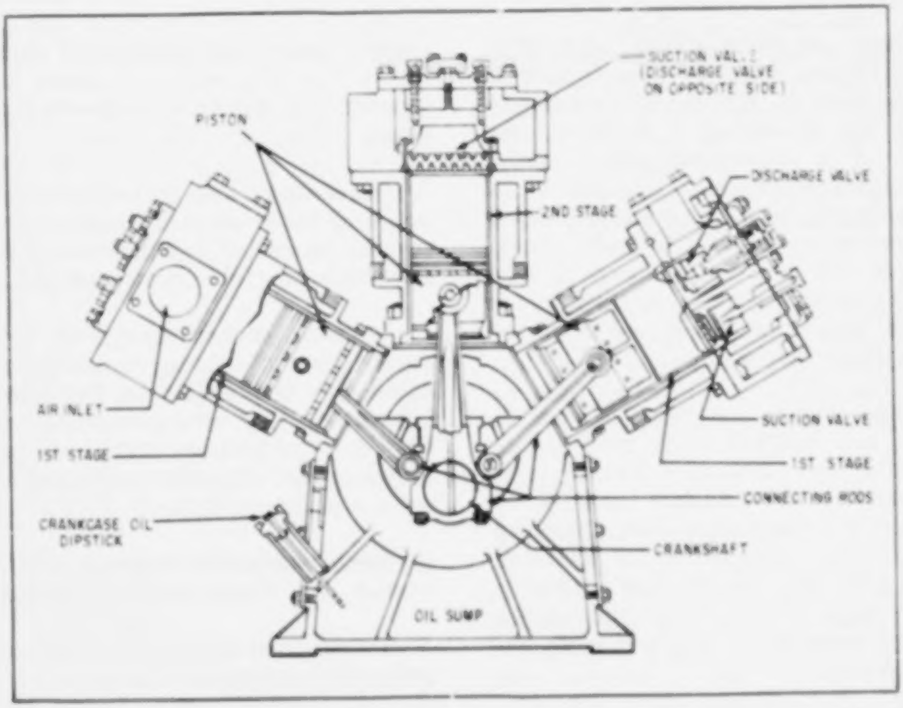
Figure 5-34.—A two-stage reciprocating air compressor.

so on. The majority of air compressors used throughout the Navy are driven by electric motors.

RECIPROCATING AIR COMPRESSORS

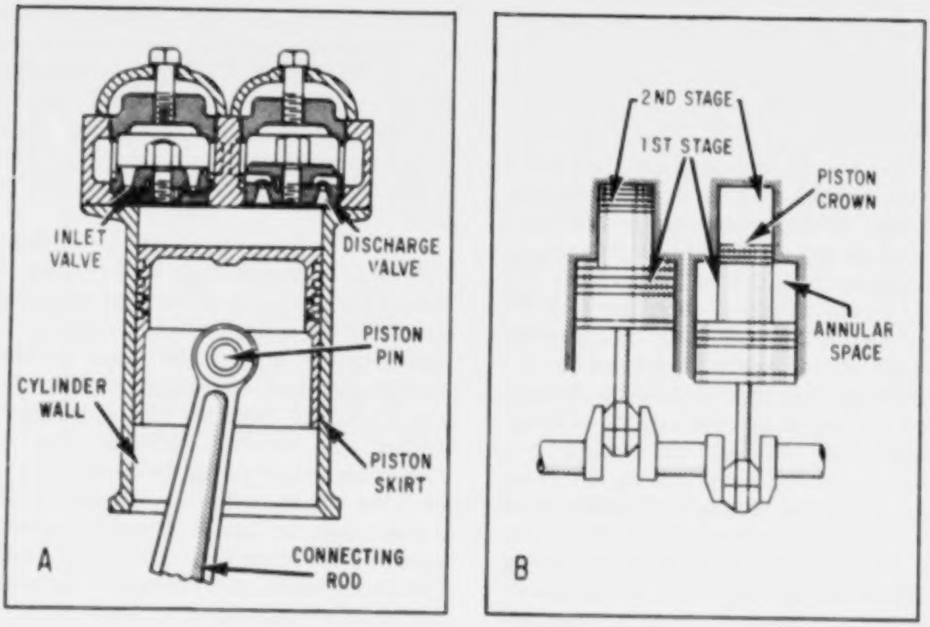
One of the most commonly used air compressors in the naval service is the reciprocating air compressor. It compresses air in the same manner as a diesel engine. A reciprocating piston alternately draws in and then compresses the trapped air in a cylinder. Since there is no internal combustion, the cycle of the reciprocating air compressor is reduced or simplified to two strokes: suction (intake) and compression. Instead of operating the valves by cam action, as in internal combustion engines, the intake and discharge valves of the reciprocating air compressor operate on the principle of differential pressure overcoming spring tension, much the same as the check valves operate in reciprocating pumps. The suction stroke occurs as the piston moves downward to create a partial vacuum and causes the intake valve to open. Air, at normal atmospheric pressure, is then drawn into the cylinder as the piston continues downward. When the piston moves on the upward stroke, the intake valve closes. The trapped air is compressed as the piston continues upward. As the piston reaches the top of its compression stroke, the air pressure developed overcomes the resistance of the spring-loaded discharge valve. The discharge valve opens momentarily and the compressed air charge then passes into the discharge line.

When higher pressure is desired, more cylinders or stages may be provided. (See fig. 5-33.) The discharge of the first stage is led to the intake of the second stage, and so on. The principle here is almost the same as that in the multistage impeller arrangements used to increase the discharge pressure on centrifugal pumps. Figure 5-34 shows a more detailed view of a two-stage reciprocating air compressor. You can see that the second-stage cylinder is noticeably smaller than the first. If there were more cylinders, each would be smaller. This is the compression process, whereby the volume of the air charge is continually reduced as it passes from one stage to the next; and, at the same time, the pressure becomes greater. Figure 5-35 shows an alternate type of low-pressure air compressor.



47.218

Figure 5-35.—Low-pressure reciprocating air compressor, vertical W configuration.



47.155

Figure 5-36.—Air compressor pistons: A. Trunk type; B. Differential type.

COMPRESSOR COMPONENTS

The pistons are either TRUNK PISTONS or DIFFERENTIAL PISTONS. Trunk pistons, as shown in view A, figure 5-36, are driven directly by the connecting rods. Since the upper end of a connecting rod is fitted directly to the piston (also referred to as wrist or trunk) pin, the piston tends to develop a side pressure against the cylinder walls. To distribute the side pressure over a wide area of the cylinder walls or liners, use pistons with long skirts. This type of piston minimizes cylinder wall wear.

Differential pistons, as shown in view B, figure 5-36, are modified trunk pistons with two or more different diameters. These pistons are fitted into special cylinders arranged so more than one stage of compression is achieved by one piston. The compression for one stage takes place over the piston crown; compression for the other stage(s) takes place in the annular space between the large and small diameters of the piston.

Drain cocks are provided at the bottom of the compressor suction control and the engine speed control. These cocks should be left open when the unit is standing idle, particularly in freezing weather. They must be closed before starting the engine.

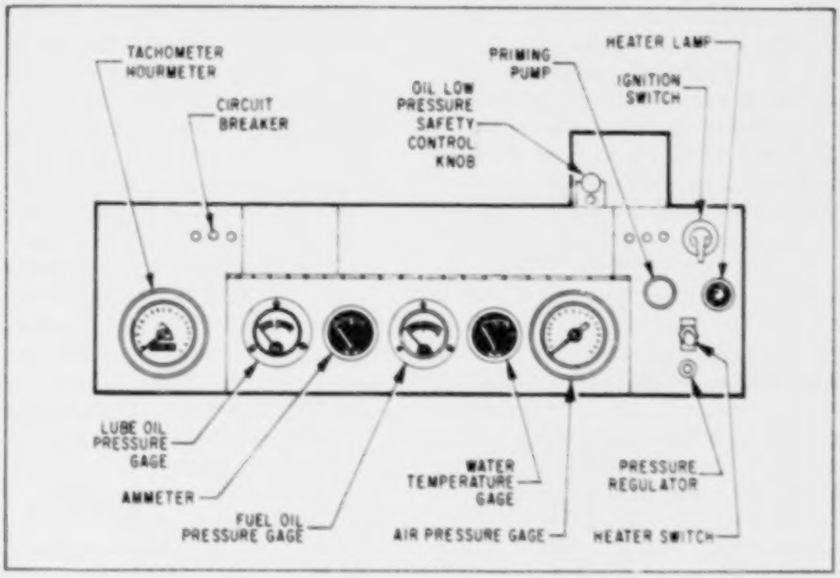
Check the oil level in the oil storage tanks as indicated by the gauge. If necessary, add oil according to the oil specifications given in the manufacturer's lubrication manual.

Drain any condensate that has accumulated in the bottom of the oil storage tanks. A drain cock is provided on the piping at the bottom of the left-hand oil storage tank. Open this cock and keep it open as long as water is draining out. Close the cock quickly when oil starts draining.

When starting the engine in mild or warm weather, you should take the following steps:

1. Open service valves about one-quarter turn—not wide open.

NOTE: Start with the service valves partly open to aid in quicker warm-up of the compressor oil.


TACHOMETER
HOURMETER
CIRCUIT
BREAKER
OIL LOW
PRESSURE
SAFETY
CONTROL
KNOB
PRIMING
PUMP
HEATER LAMP
IGNITION
SWITCH
LUBE OIL
PRESSURE
GAGE
AMMETER
FUEL OIL
PRESSURE GAGE
WATER
TEMPERATURE
GAGE
AIR PRESSURE GAGE
PRESSURE
REGULATOR
HEATER SWITCH

115.383

Figure 5-37.—Instrument panel.

2. Ensure the clutch is engaged.

3. Position the low-pressure, engine-oil-system safety-control-knob to ON (fig. 5-37).

4. Turn the ignition switch to the start position. Immediately after the engine starts, release the ignition switch. If the engine fails to fire within 30 seconds, release the ignition switch and allow the starting motor to cool off for a few moments before trying the starter again.

5. With the engine running, check the engine oil pressure gauge. If no pressure is indicated, turn the engine off. When the oil pressure indicates above 22 psi, continue to operate the engine and check the low-pressure engine-oil switch. The knob on this switch should be in the RUN position.

NOTE: The engine oil pressure gauge vibrates until the engine oil warms up.

6. After the engine has run about 3 minutes, check the engine coolant temperature gauge. The gauge should indicate less than 210°F. If the gauge is showing more than 210°F, SHUT OFF THE ENGINE.

7. After 5 minutes of operation, close the service valve and attach the hose or service line of the tool or device to be operated.

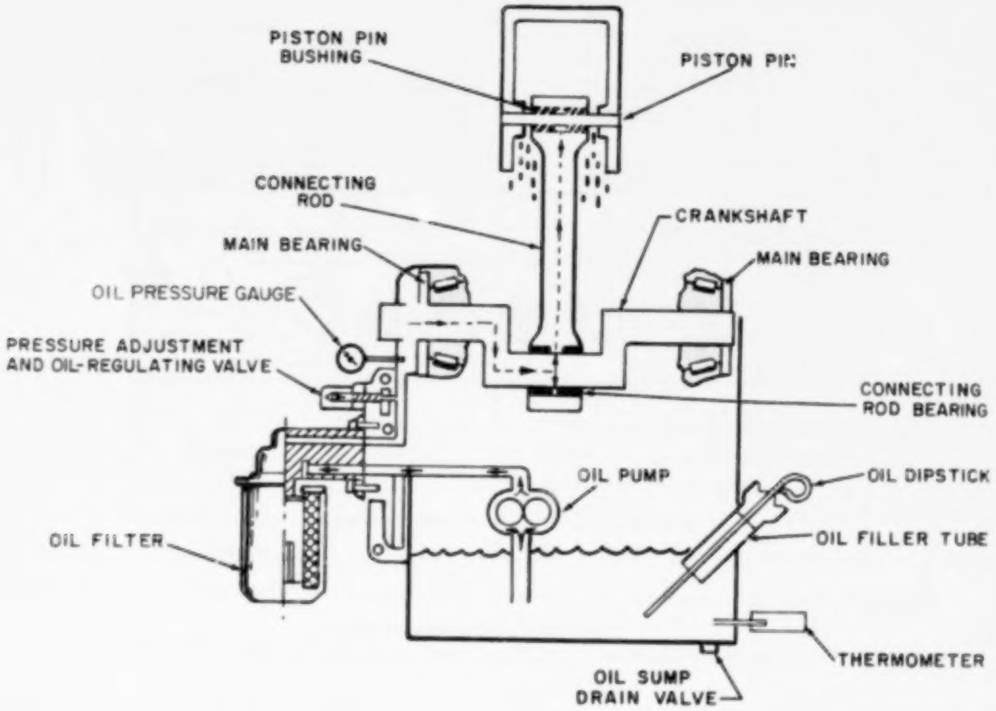
8. Open the service valves fully and start the work. After start-up, the unit automatically provides compressed air at the discharge service valves. Now you only have to check the gauges on the instrument panel.

9. When starting the engine during the day, after the first daily start-up, you can forget warm-up.

To stop the unit at the end of the day's run, first close the service valves and let the engine run at idle for 5 minutes; soon, the engine coolant temperature levels off and the entire unit cools down. Now turn the ignition switch to the OFF position.

LUBRICATION SYSTEM

Except for oil-free (nonlubricated) compressors, high-pressure air compressor cylinders are generally lubricated by an adjustable force-feed lubricator driven from a reciprocating or rotary part of the compressor. Oil is fed from the cylinder lubricator by separate lines to each cylinder. A check valve is installed at the end


PISTON PIN BUSHING
PISTON PIN
CONNECTING ROD
CRANKSHAFT
MAIN BEARING
MAIN BEARING
OIL PRESSURE GAUGE
PRESSURE ADJUSTMENT AND OIL-REGULATING VALVE
CONNECTING ROD BEARING
OIL PUMP
OIL DIPSTICK
OIL FILTER
OIL FILLER TUBE
THERMOMETER
OIL SUMP DRAIN VALVE

47.222

Figure 5-38.—Lubricating oil system of a low-pressure air compressor.

of each feed line to keep the compressed air from forcing the oil back into the lubricator. The oil is distributed to the top of each main bearing, to spring nozzles for reduction gears, and to outboard bearings. The crankshaft is drilled so oil fed to the main bearings is picked up at the main bearing journals and carried to the crank journals. The connecting rods contain passages that conduct lubricating oil from the crank bearings up to the piston pin bushings. As oil leaks out from the various bearings, it drips back into the oil sump (in the base of the compressor) and is recirculated. Oil from the outboard bearings is carried back to the sump by the drain lines.

Low-pressure air compressor lubrication is shown in figure 5-38. This system is similar to the running gear lubrication system for the high-pressure air compressor.

Nonlubricated reciprocating compressors have lubricated running gears (shaft and bearings) but no lubrication for the pistons and valves. This design produces oil-free air.

The lubrication chart in the operator's manual for the make and model of compressor you are operating shows you where the unit should be lubricated, how often to lubricate, and what lubricant to use. The frequency depends upon operating conditions. Operating under abnormal conditions requires more frequent service.

CAUTION: Before servicing the compressor air system or compressor oil system, open the service valves to the atmosphere to relieve all pressure in the systems.

UNLOADING SYSTEMS

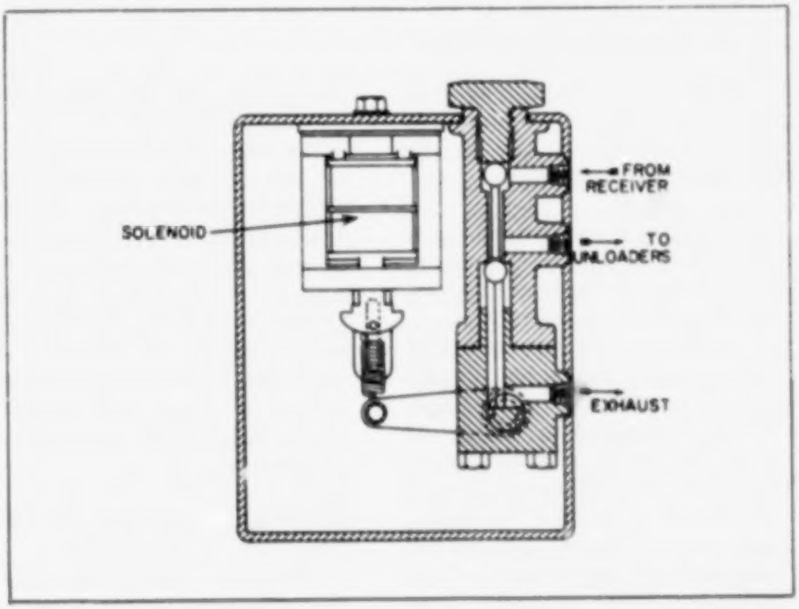
Air compressor unloading systems are installed to remove all but the friction loads on the compressors; that is, they automatically remove the compression load from the compressor while the unit is starting and automatically apply the load after the unit is up to operating speed. For units with start-stop control, the unloading system is separate from the control system. For compressors equipped with constant-speed control, the unloading and control systems are integrated.

A few typical compressor unloading methods are discussed in the paragraphs that follow. These methods include closing or throttling the compressor intake, holding intake valves off their seats, relieving intercoolers to the atmosphere, relieving the final discharge to the atmosphere (or opening a bypass from the discharge to the intake), opening up cylinder clearance pockets, using miscellaneous constant-speed unloading devices, and combinations of these methods.

As an example of a typical compressor unloading device, consider the MAGNETIC-TYPE UNLOADER. Figure 5-39 shows the unloader valve arrangement. This unloader consists of a solenoid-operated valve connected with the motor starter. When the compressor is at rest, the solenoid valve is de-energized to admit air from the receiver to the unloading mechanism. When the compressor reaches near-normal speed, the solenoid valve is energized to release the pressure from the unloading mechanism and to load the compressor again. For details on the unloading devices, refer to the pertinent manufacturers' technical manuals for compressors installed in your command.

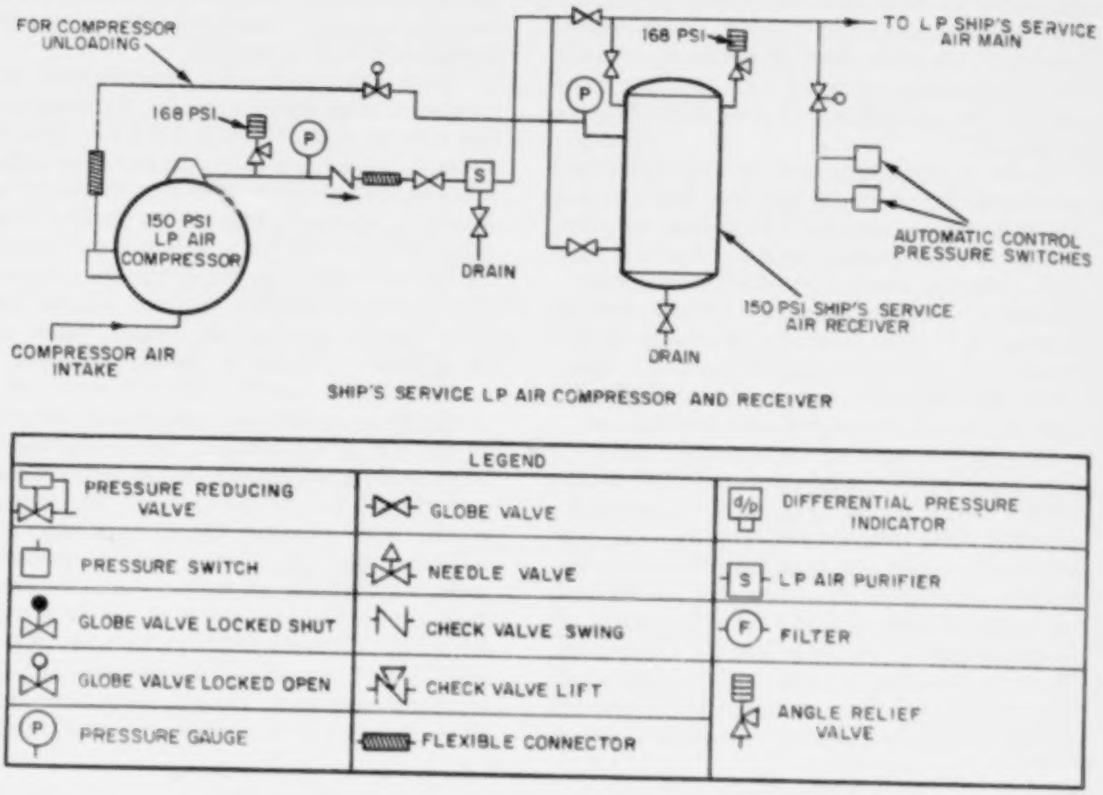
Since compressors draw in ambient air, or the air surrounding the compressor, the intake is fitted with an AIR INTAKE FILTER. This filter keeps the intake air free of dust and other airborne particles. If dust-laden air entered the compressor, internal combustion, triggered by the heat of compression, can take place within the cylinders.

Moist or humid air drawn into the compressor cylinders poses another problem. The air intake filter cannot prevent this water vapor from being taken into the compressor. Instead, the water vapor is usually squeezed out of the air during compression and transformed into steam by the heat of compression. The steam condenses to form moisture droplets downstream from the compressor as the compressed air charge is cooled. Since moisture can damage some of the machines that use compressed air (pneumatic tools, for example), the moisture must be removed from the air before it is sent to the storage tank. So, a FILTER and a MOISTURE SEPARATOR ASSEMBLY are placed between the compressor and the storage tank. The assembly removes most of the moisture, or any other impurities, entrained



47.158

Figure 5-39.—Magnetic-type unloader.


FOR COMPRESSOR UNLOADING
168 PSI
150 PSI LP AIR COMPRESSOR
COMPRESSOR AIR INTAKE
DRAIN
168 PSI
TO L.P. SHIP'S SERVICE AIR MAIN
AUTOMATIC CONTROL PRESSURE SWITCHES
150 PSI SHIP'S SERVICE AIR RECEIVER
DRAIN
SHIP'S SERVICE LP AIR COMPRESSOR AND RECEIVER
LEGEND
PRESSURE REDUCING VALVE
PRESSURE SWITCH
GLOBE VALVE LOCKED SHUT
GLOBE VALVE LOCKED OPEN
PRESSURE GAUGE
GLOBE VALVE
NEEDLE VALVE
CHECK VALVE SWING
CHECK VALVE LIFT
FLEXIBLE CONNECTOR
DIFFERENTIAL PRESSURE INDICATOR
LP AIR PURIFIER
FILTER
ANGLE RELIEF VALVE

47.225

Figure 5-40.—LP air compressor piping arrangements.

in the air before it is sent on to storage. The assembly is fitted with a valve or drain cock so that accumulations of water and dirt can be drained now and then by the operator.

The tank that stores the compressed air is called the AIR RECEIVER, as shown in figure 5-40. In this way, demands for compressed air are made upon the receiver rather than directly on the compressor itself. And, there is little chance of the demand for air exceeding the supply. To this end, the air receiver has with it some type of control system or device to monitor the supply of compressed air in the receiver. The control device may be a PRESSURE SWITCH that senses predetermined thresholds or levels of pressure. When the compressor has sufficiently charged the receiver with compressed air, the pressure switch automatically opens and shuts down the compressor. If and when the demand for compressed air begins to drain the receiver to a preset pressure threshold, the pressure switch closes and automatically starts the compressor.

In systems where the demand for air is more or less constant and prolonged, a type of CONSTANT-SPEED CONTROL can be used. The compressor is permitted to run continuously to keep the receiver charged with air, while the constant-speed control functions somewhat like a pressure relief valve. If the pressure of the compressed air in the receiver rises, because of a momentary drop in demand within the system, the control simply vents the excess compressed air to the atmosphere rather than shut down the compressor.

COMPRESSOR COOLING SYSTEMS

The generation of heat always accompanies the compression of air. In most low-pressure air compressors, the heat from compression is dissipated before the temperature gets too high.

Aluminum cylinders have cooling fins, and a fan forces cooling air past the cylinders. In most medium-pressure and high-pressure air compressors, the compressor has to be cooled with pump-circulated water. The cooling water is circulated in much the same fashion as in an automobile engine with the coolant passing through jackets in the cylinder walls, cylinder heads, and so on.

In addition, compressors are fitted with other cooling devices known as intercoolers and aftercoolers. Generally, these devices consist of a series of tubes, either air-cooled or water-cooled, through which the compressed air charge flows after leaving the cylinders. These devices cool the compressed air. INTERCOOLERS are placed between the stages or cylinders of multistage compressors. Thus, they cool the compressed air charge before it is drawn into the next cylinder. The AFTERCOOLERS cool the final discharge of air from the compressor. Both the intercoolers and the aftercoolers are of the same general construction, except the aftercoolers are designed to withstand a higher working pressure.

Perhaps the most important advantage of these coolers is they aid in keeping the air charge in a compressed state. In other words, hot air has a tendency to expand, and if the compressed air charge is not cooled, it too tends to expand and thereby liberate much of its pressure or energy.

COMPRESSOR LOCATION

Locate the compressor unit so that it is reasonably level. The design of this unit permits a 15° lengthwise and a 15° sidewise limit on out-of-level operation. The engine, not the compressor, is the limiting factor. When the unit is to be operated out of level, keep the engine crankcase oil level near the high level mark (with the unit level), and have the compressor oil gauge show nearly full (with the unit on the level).

The mechanical parking brake lever is near the bumper. Set the brake by pulling or pushing the lever as directed by a decal or stencil located beside the lever on the unit.

The parking brake should always be set once the air compressor is on location to prevent accidental rolling of the unit, which could cause not only mechanical damage but also possible injury to personnel. As an added precaution, the wheels should be chocked when possible.

Open the side curtains on both sides of the enclosure and leave them open whenever the unit is in operation. When the side curtains are closed and the engine running, the flow of air through the oil cooler and engine radiator is impeded because of poor air circulation within the enclosure. The curtains may be left closed for a few minutes during starting procedures in cold weather to ease engine warm-up. However, when the compressor goes to work, open the side curtains. For specific operating instructions, check the instruction plate attached to the unit being used.

ENGINE

The heart of the compressor is the engine, which furnishes power for the compressor and produces air for the pneumatic tools used during drilling. Know how to properly start, operate, and maintain the compressor engine. In most cases, the general operating procedure is similar to that given below.

Check the engine oil level. If necessary, add oil as recommended in the engine manual. Do not overfill.

Check the engine cooling system. The radiator should be filled to the bottom of the filler neck. If necessary, add soft, clean water until full. In cold weather, use a permanent antifreeze with a rust inhibitor. Ethylene glycol solutions are recommended because they do not evaporate and only water is added to maintain a full system.

Two fuel tanks are furnished, one on each side. The two tanks are cross-connected to permit filling from either side of the unit. Clean fuel is vitally important. Ensure clean fuel is poured or pumped into the tanks. Be sure no condensate (water) lies in the bottom of the fuel tanks. Drain off any water that may be there. Clear away obstructions in the way of the fuel tanks' vents.

Lubricate all parts of the engine as recommended in the manufacturer's engine manual. Make periodic checks of the oil filter, fuel filter, and fuel oil pump screen. Ensure the rain cap on the exhaust pipe swings freely so a back pressure on the engine exhaust cannot be created. Check the battery cells for the proper liquid level. A pair of two-stage dry-type air cleaners filter the intake air for the compressor suction and engine air-intake manifold. Both cleaners are under the canopy at the compressor end of the unit.

The first stage of the air cleaner uses centrifugal precleaning which rotates the intake air and separates a large portion of the dust collected in the dust cup. The dust cup should be checked and emptied daily.

The second stage of the air cleaner consists of a group of cylindrical pleated paper elements. The ends of the pleats are molded into a flexible plastic faceplate that seals the cartridge in place in the air cleaner housing without additional gaskets. On the side of the air cleaner housing is mounted a service indicator. As the second-stage cartridge loads up with dirt, a red indicator flag gradually rises in the window. When the cartridge is completely loaded, the window shows all red, and the flag is locked in place. This is the time to replace the second-stage cartridge. Discard the old cartridge and reset the red flag so the window shows clear. Do not clean used paper cartridges.

OPERATION AND MAINTENANCE OF AIR COMPRESSORS

Before starting the compressor, the operator should make inspections to ensure that both the compressor and the auxiliary components are ready for operation. This procedure includes the following: checks of the control and unloading systems; inspection of safety valves or pressure relief valves; draining condensate from the coolers, separator, and receiver; and turning on cooling-water services and opening valves to ensure proper circulation of water through the compressor and coolers.

Once the compressor is in operation, the operator must periodically check the temperature and pressure of the cooling water, lube oil, and compressed air. The lube oil level must also be checked and maintained at the proper level. Coolers must be inspected for correct temperature and flow of water. Accumulations of moisture in the coolers, separator, and air receiver must be drained periodically.

In addition, maintenance schedules require more detailed inspections (monthly, quarterly, and so forth). In many cases, these inspections require dismantling parts of the compressor and auxiliary equipment. For instance, the operator may be required to inspect intake and discharge valves, cylinders, and pistons. The air intake filter must be inspected periodically and cleaned as necessary. The coolers and the receiver must also be inspected for corrosion and accumulations of dirt and oil.

The lubrication system on most compressors is somewhat similar to that on an automobile engine. Normally, the compressor base is used as the lube oil sump and oil pump housing. The oil level can be measured by a dipstick or an oil level sight-gauge mounted on the base. The lube oil is distributed through various passages to lubricate bearings, valves, pistons, and other internal parts. An oil film is also distributed over the cylinder walls. Although small amounts of lube oil may mix with the compressed air, it is usually filtered out at the separator assembly. Note that one of the periodic operator inspections on air-lift pumps is to check the air-water discharge from the pump for contamination by lube oil entrained in the compressed air.

The lube oil used in the cylinders must be of the right type. The auto-ignition point (temperature at which oil vapor burns without the presence of a spark or flame) of these oils must always be well above the highest heat of compression. Otherwise, there is the danger of internal combustion in the compressor cylinders. An example of a SEABEE operated and maintained compressor is discussed in the paragraphs below.

The 600 ft^3/min, portable, air compressor is a single cylinder, sliding vane, oil-cooled, positive displacement rotary compressor, connected through a friction disk clutch to a heavy-duty industrial diesel engine (fig. 5-41). The complete assembly is equipped with a semi-elliptical spring mounting, pneumatic tires, and drawbar.

The portable compressor comes equipped with all components essential for proper operation, including the following:

- A heavy-duty, single, dry-type air cleaner to provide clean air for the compressor and engine with a minimum of service requirements.

- Large cooler and radiator elements with ample capacity for efficient, dependable cooling of the compressor oil and engine coolant.

- Oil filters with replaceable cartridges for efficient filtration of the compressor oil and engine crankcase oil.

- Automotive-type instrument panel with easy-to-read gauges and electrical instruments.

- Pneumatic regulating controls that provide for economical engine operation under all loads.

- A combination thermostatic valve and bypass to assure rapid warm-up and optimum compressor performance over a wide range of surrounding air temperatures.

- An electrically operated shutdown system to stop the engine if a malfunction occurs in the compressor and/or engine.

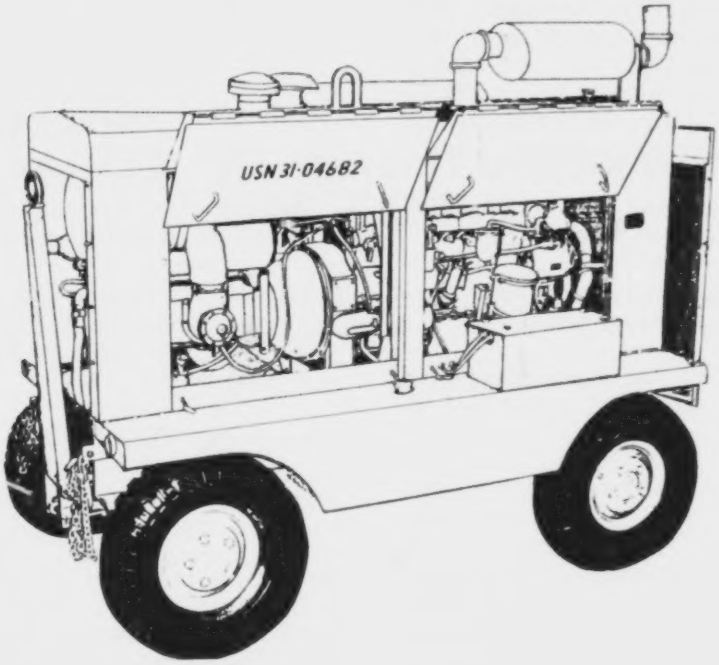


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Figure 5-41.—Air compressor.

- A blowdown valve to relieve the pressure in the receiver and airflow system automatically each time the engine is shut down.

- An oil flow system that eliminates the need for an oil circulating pump.

SAFETY PRECAUTIONS

In the paragraphs below are some tips on how you can avoid air compressor accidents.

- Keep the hose connections of portable air compressors tight, and inspect these connections often to ensure they remain tight.

- Check the safety valves and gauges frequently to be sure they are working right.

- Use fixed towbars, NOT chains or ropes, when moving this equipment. Do NOT tow any faster than the design of the wheel bearings allows.

- Check the wheels of portable air compressor carriages to ensure they work safely.

- Learn and practice safety when you work with motors, air compressors, and air receivers.

- When starting an air compressor, check the safety valves, pressure controls, and regulators to determine that they are working properly.

- Do NOT leave the compressor station after starting the compressor unless you are certain the control, unloading, and governing devices are working properly.

- Do NOT run an air compressor faster than the speed recommended by the manufacturer.

- Be sure air at the intake is cool and free from flammable gases, vapors, or dust.

- Do NOT permit wood or other flammable materials to remain in contact with the air discharge pipe.

- Immediately secure a compressor when the temperature of the air discharged from any stage rises unduly or exceeds 400°F.

- Do NOT install a drop valve or check valve between the compressor and receiver unless a relief valve is also fitted between the compressor and the stop or check valve. (If the compressor is started against a closed valve or a defective check valve, the air cannot escape and an explosion can result.)

- Pressure gauges must be in working order unless you have to remove them for repair.

- NEVER kink a hose to stop the airflow. Keep the clamps on the hose tight.

- Keep compressor, tanks, and piping clean to guard against oil vapor explosion. Clean intake air filters periodically.

- Use only soapy water or another suitable nontoxic, nonflammable solution for cleaning compression intake filters, cylinders, or air passages. NEVER use benzene, kerosene, or other light oils to clean these portions of a system. These oils vaporize easily and form a highly explosive mixture under compression.

- Turn off the motor before adjusting and repairing an air compressor.

- Before working on or removing any part of a compressor, ensure that the compressor is secured and cannot be started automatically or by accident, that air pressure in the compressor is completely relieved, and that all valves between the compressor and the receivers are closed.

- Know what compressors can do; realize they are dangerous; and then use them safely.

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CHAPTER 6

FIELD WATER TREATMENT EQUIPMENT AND PROCESSES

Learning Objectives: Recognize methodology used for water treatment and purification; and identify the types of water purification units being used in the fields.

Water is never absolutely pure. Impurities vary from dissolved gases, chemicals and minerals, to suspended matter like disease germs and dirt. Some can be seen and some cannot; others can be detected by taste or odor, or only by laboratory tests. This chapter covers the water cycle, the quality of water, the waterborne diseases, the treatment and purification of water, and the types of purification units.

Water treatment is closely related to the health of a unit. Improper treatment of water can cause infectious intestinal diseases and skin fungus. The responsibility of ensuring a supply of pure water in the SEABEEs is shared by the unit commander and the Navy Medical Service. As a Utilitiesman, you may perform major duties involving the treatment and purification of water, so it is safe to use for drinking, cooking, bathing, and so on.

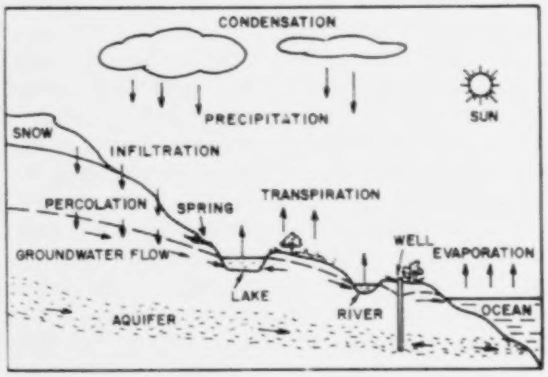

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Figure 6-1.—The hydrologic cycle.

THE WATER CYCLE

Water is circulated from the oceans to the atmosphere by a series of processes and then to the surface of the earth and beneath it. This is known as the water cycle, or hydrologic cycle (fig. 6-1).

An understanding of the occurrence of groundwater is based on a general knowledge of these processes and their relationships to each other. Basically, the cycle consists of the following processes: evaporation of water from oceans; its condensation to produce cloud formations; precipitation of rain, snow, sleet, or hail upon the land surface; dissipation of the water by direct runoff into lakes and streams; seepage, or infiltration, of rainwater or melted snow into the soil and then into underlying rock formations; movement of water through the openings in the rocks and at the surface through springs, streams,and lakes; and direct evaporation.

The cycle usually does not progress through a regular sequence and may be interrupted or short-circuited at any point. Moisture that condenses over the ocean may fall into it as rain. Rain that falls upon a heavily forested area soon may return to the atmosphere by direct evaporation or through transpiration by plants. Jungle-covered islands of the Southwest Pacific are known to produce more evaporation than adjacent areas of ocean. Water that seeps into the soil may be retained for a time by soil capillarity or other means before moving downward through the unsaturated zone to become a part of the groundwater.

As the rainfall and water cycle repeats itself, depending upon the climatic and other conditions, a water supply is building up that can be captured and used for a multitude of purposes. Roughly, this basic water supply is divided into two categories: surface water and groundwater. These two categories are discussed below.

SURFACE WATER

Surface water is water that is flowing in our streams or rivers, resting in our lakes and ponds, or flowing in the sea. Its origin lies in the water which falls from the atmosphere, together with that which flows from the ground under certain circumstances. The water precipitated upon the earth's surface from the atmosphere can be in the form of rain, snow, sleet, fog, or dew. Depending upon the character of the soil, this precipitated moisture is partly absorbed by the soil, partly evaporated or transpired by plant growth, with the remainder caught in surface depressions or flowing over the surface to natural stream beds where it continues on its way to the sea or into the crevices of the earth.

In olden days, it was thought that the vast underground water storage reservoirs were fed by surface streams. This is only partly true. In many cases, when geological conditions permit, the groundwater sources feed the stream instead. It is true that the underlying beds of some surface streams are composed of sands and gravels and other materials deposited through the ages by sedimentation or glacial action and, in these cases, water from the stream sometimes trickles down by gravity through the stream bottom into the underlying sands or gravel. When this happens, the water in these bottom gravels generally flows in the same direction as the stream itself. In other cases, it may be held in storage by natural barriers in the path of its flow. These underlying sands and gravels, generally referred to as "alluvium," are discussed under groundwater. In many cases, river beds become completely dry while the flow through the alluvium continues. This occurs in many cases in the western sections of the United States and on the Pacific Coast of North America, particularly in the Southwest.

GROUNDWATER

Groundwater is that part of the water or moisture that has precipitated from the atmosphere upon the earth's surface and has been absorbed by the soil and collected below a certain level called the "waterline." In any discussion of groundwater, the waterline is of utmost importance and interest. The processes by which a groundwater supply is built up will now be examined. It is understood that the uppermost part of the earth's surface is composed of layers of materials of a varying nature. Generally, there is a topsoil capable of sustaining plant growth. This topsoil is composed largely of minute particles of rock mixed with decayed vegetable matter or other material. The topsoil is underlaid by a layer of material, generally referred to as "soil." Soil is composed of minute particles of rock mixed with various materials, sometimes of vegetable or animal origin, but often containing nothing more than materials of mineral origin. The depth of the soil bed is not fixed and may vary from a few inches to several feet.

Under the soil layer is the top layer of rock, which is decomposed in some measure and which at a deeper level becomes more solid. Ultimately this rock becomes solid, as it was in the original cooling process. That part of the earth's crust between this solid rock and the earth's surface is of interest in discussing groundwater. Again, the depth of this outer layer is a variable, for it has previously been pointed out that in many locations the virgin rock, itself, appears at the surface with no overlying decomposed rock or soil. Certainly, groundwater could not be found at such locations.

Now, consider the layer of decomposed rock which is between the uppermost layer of soil and the solid or virgin rock itself. Here, during the ages, many things have happened. The action of the elements, atmospheric conditions, earthquakes and upheavals, volcanic action and chemical reactions, as well as pressure conditions and other influences have caused this layer to become anything from a semisolid rock to a conglomeration of layers of various materials. Generally, these layers of materials, referred to as "strata," follow the contour of the earth's surface; however, in many cases, they outcrop at the surface and slant downward in any direction. These strata may be composed of sand, gravel, broken stone of all sizes and character, minerals of all kinds, and even layers of solid rock. Some of the softer materials are shales, chalk, clays, gypsum, and so forth. The harder materials consist of limestone, granite, quartzite, flint, silica, dolomite, and other minerals. The types of material depend on the geographical location and the conditions under which the topmost layers of rock were formed. In the formation process, because of earth movement and other influences, these varying strata were bent, folded, and broken in such fashion that it is not possible to chart their exact course through the upper part of the earth's crust. Their presence and their position relative to each other are important to the storage and production of groundwater.

Depending upon the composition of these various strata, they either absorb the water which falls from the sky or flows at a level above them, or they reject this water and form a bed upon which the water flows in one direction or the other. The capacity of the material composing any stratum to transmit water under pressure is called its "permeability." The property of the material of any stratum to contain interstices, or openings, is called its "porosity." Both the permeability and porosity of the rock formation determine whether groundwater can be found in suitable amounts at any particular location.

The water cycle has previously been explained. When water falls on the ground, the part of it that becomes groundwater by reason of the soil or surface characteristics, is absorbed into the earth. It is then either held in suspension or flows downward by gravity to a point beyond which it cannot pass. It then flows in any direction provided the permeability of the particular stratum holding it permits. When the permeability of the stratum does not permit such flow, the water remains confined at that point. As more water percolates downward through the soil or rock, the top level of the confined water rises until flow becomes possible in one direction or the other through a more permeable formation. More water must come from a higher level to sustain such a flow. Finally, the amount of water percolating from the higher levels balances the amount of water flowing laterally away, and the top level of the main body of groundwater is stabilized. The upper surface of this main body of groundwater, when stabilized under any condition of flow, constitutes the water table for any specific locality. The water table is not fixed, however. It rises and falls according to the varying amounts of water percolating from above, called the "influent" supply, and those amounts flowing away or withdrawn, called the "effluent" flow. A stratum that bears groundwater is termed an *aquifer*.

Water beneath the surface of the earth occurs in three zones: the zone of soil moisture where water temporarily is held in pore spaces by capillarity and other soil conditions; the zone of aeration, or zone of percolation, beneath the soil layer where both water and air are present in the pore spaces; and zone of saturation, where all spaces are filled with water. These zones are shown in figure 6-2. The top of the saturated zone is called the "water table." It is not flat, but has a variable depth beneath the surface, depending upon surface topography, rainfall, direction of water movement, rock structure, and porosity. Water in the zone of soil moisture may evaporate directly or through transpiration by plants or may percolate downward into the zone of aeration and thence to the zone of saturation. Permeable rocks in the zone of saturation yield water to wells, but wells ending in the zone of aeration produce no water.

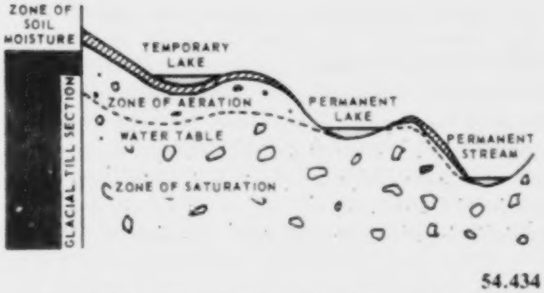

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Figure 6-2.—Classification of underground water.

Sometimes in the cooling-off process or because of other external and internal influences, a stratum of material that does not permit the passage of water has been heaved about into a cup-shaped formation at a point in the zone of aeration higher than the established water table. In time, this cup is filled with groundwater and a "perched" or false water table is established. This is a serious problem to those attempting to develop a groundwater supply. The perched supply, if pumped, is soon exhausted and depends alone upon seepage from above for replenishment. Many of these perched supplies result from folded clay formations in the zone of aeration that stop the percolation of water downward. Perched water never forms a dependable water supply.

THE QUALITY OF WATER

Preliminary to discussion of water production, the "quality" of available water supplies must be briefly considered. Whether the water supply comes from the surface or underground, the supply must suit its intended use. Either source may produce water with too high a concentration of mineral salts, color, suspended matter, incrusting or corrosive agents, or bacteria that prevents the use of water in its natural state for the purpose intended. If suitable water cannot be found, then other available sources must be used. The water must be treated to remove those elements that make its direct use impossible. For human consumption, all harmful bacteria must be destroyed and the concentration of certain mineral salts and suspended matter reduced to a level that makes the water safe to drink or to use in preparing food. Industries sometimes have to treat their raw-water supply to meet the requirements of the manufacturing processes. Boiler feedwater must often be treated to prevent sludge from forming in the boiler and scale from forming on the metal surfaces. Most towns and municipalities must treat their water supply by some method before distributing it for general use. Water, whatever the source, must be available in quantity and quality to meet its intended use.

THE WATERBORNE DISEASES

In this section, various diseases caused by the use of water that is impure and unsafe are discussed. Some of the methods of treatment and purification used in the field to eliminate impurities in water are also discussed. Additionally, you are introduced to types of purification equipment with which you, as a Utilitiesman, should be familiar.

Water flowing over the earth's surface picks up dirt, disease organisms, chemicals, and anything else in its path that can be dissolved or moved. Water that soaks into the ground loses many of its suspended impurities as it filters through the earth. Although the water becomes clearer, it dissolves minerals and other chemicals at the same time. Groundwater may be clear, but it is not pure and may contain harmful disease organisms and chemicals.

Waterborne diseases do not appear immediately after drinking contaminated water. Disease-producing organisms need time to grow and multiply inside a person before they cause illness. The time between drinking contaminated water and the appearance of the disease is called the incubation period. Absence of disease symptoms for several days after drinking untreated water is no guarantee that the water is pure. Lack of disease symptoms in the natives is no test either, as they may have become immune.

IMPURITIES IN WATER

Water can be a source of danger and destruction because of the many impurities often found in it. Actually, you can expect to find impurities in practically all water. Some of these impurities do not amount to much, while others are extremely dangerous to health. Impurities in water can be broken down into two major categories: dissolved impurities and suspended impurities.

DISSOLVED IMPURITIES are organic or inorganic materials or chemicals that cause an unpleasant taste, color, or odor in the water.

SUSPENDED IMPURITIES include organisms, as well as organic and inorganic materials, that usually make the water turbid or muddy looking. Suspended impurities are usually more dangerous to health than dissolved impurities. The suspended impurities consist of mineral matter, such as sand, silt, or clay; of disease organisms, such as bacteria or protozoa; and of water plants, such as algae. It is absolutely necessary to remove or destroy the disease-producing organisms in water to be consumed by people.

TYPES OF WATERBORNE DISEASES

Water carries many of the organisms that produce disease. Disease-producing organisms carried by water occur in two classes: those readily destroyed by chlorination and those that are chlorine resistant. Although the chlorine-resistant organisms require careful treatment, they can be destroyed by purification methods.

Waterborne diseases caused by dangerous organisms include typhoid, paratyphoid, cholera, amoebic dysentery, schistosomiasis, and diarrhea. The following discussion stresses continual care and inspection of the water supply, because waterborne diseases spread if not treated properly.

Typhoid Fever

TYPHOID FEVER is an intestinal disease caused by the bacterium known as bacillus typhosus. Symptoms of this disease are rose-colored eruptions of the skin, accompanied by a high fever (lasting about 4 weeks) and frequent bowel movements. Typhoid fever organisms are readily destroyed by field chlorination methods. Most waterborne diseases do not appear immediately after using contaminated water, as they need time to grow after entering a person's system. This time to grow is the incubation period.

Paratyphoid Fever

PARATYPHOID FEVER is similar to typhoid in sources of infection and in symptoms; the organisms are, like the typhoid bacillus, readily destroyed by field chlorination methods.

The incubation period varies from 4 to 10 days. An attack gives a person immunity from a second attack of paratyphoid, but does not give immunity from typhoid.

Cholera

CHOLERA germs are discharged from the body in feces where they live for several days. When water in any form contacts this germ, it is carried along and multiplies.

Amoebic Dysentery

AMOEBIC DYSENTERY is an infectious intestinal disease. Symptoms are eruptions of the skin and frequent bowel movements. This disease is caused by a small animal instead of bacteria and resists ordinary chlorination. It is carried by amoebic cysts that foray in the intestines, then are discharged in the feces. Cysts (shell or sack) protect them and, when in water or moistened, they live for many days, but drying destroys them. The diatomite filter removes the cysts and superchlorination destroys them.

Schistosomiasis

SCHISTOSOMIASIS is caused by a small worm that enters the body through consumption of contaminated water. Or, it may enter through the skin while a person is bathing or swimming in contaminated water. Eggs of this parasite (commonly called blood flukes) are discharged from an infected person through the urine or feces. In fresh water, these eggs hatch into very small, free-swimming larvae which are not infectious to humans. However, if these larvae can find freshwater snails to enter, they develop into the next form "cercariae," and become highly infectious to human beings. In water, larvae can live for only 24 hours, and cercariae for only 36 hours. The effective remedy is to destroy all the snails at the water source. Once the snails are destroyed, the cycle is broken and the disease ceases.

Diarrhea

DIARRHEA is a name given to several intestinal diseases characterized by cramps and frequent bowel movements with watery feces. Inadequate sanitary protection of food and water can cause diarrhea. Where the disease is caused by food, it is restricted to those who consume the contaminated food; waterborne infection is likely to be widespread. Proper chlorination measures will control waterborne diarrhea.

In addition to the specific waterborne diseases discussed above, there are several nonspecific disorders caused by impure water. One example is the staining or discoloring of teeth because of the presence of florides in drinking water. Surely you are well aware by now that maintaining a good safe supply of drinking, washing, and bathing water—free from diseases and pollution—is one of your primary responsibilities.

TREATMENT AND PURIFICATION

Various methods of treatment and purification are used to eliminate impurities in water and, insofar as possible, make it pleasant to drink. You should be familiar with some of the principal methods commonly used, keeping in mind that safe, pure water is essential to naval operations everywhere. How well you carry out your duties in the treatment and purification of water concerns the health and welfare of all personnel using the water.

Methods used in various combinations in the field treatment and purification of water include flocculation, sedimentation, filtration, and disinfection. A brief discussion on these methods follows.

FLOCCULATION

COAGULATION is a formation of gelatinous particles in water by chemical action. FLOCCULATION is the combination of these particles into a heavy precipitate (floc) that absorbs color and entangles bacteria and other suspended matter as it settles.

A common floc-forming chemical is aluminum sulfate (filter alum). When sufficient natural alkali is not present in the water to form a good floc, additional alkali (soda ash) must be added. Observe figure 6-3; this will give you an idea of how flocculation works. Mechanical devices, such as mixers, agitators, and baffles, are an advantage in flocculation since they keep the precipitate suspended in the water long enough to produce a heavy floc.

SEDIMENTATION

If you were to dip up a glassful of water from a moving stream and proceed promptly to observe

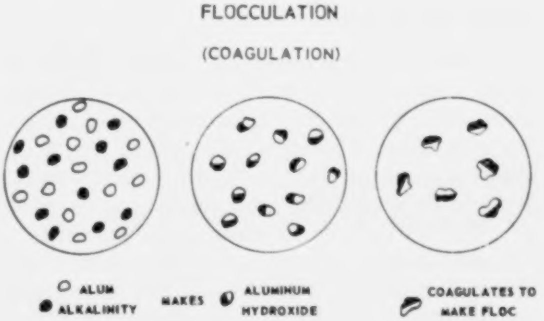

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Figure 6-3.—The process of flocculation.

its contents, you would probably discover a number of solid particles being held in suspension in the liquid. At first these particles are more or less equally dispersed; but as the water becomes still, they start settling to the bottom of the glass. The settling of solids in this manner is caused by the natural action of gravity. In the field of water treatment, clearing water of turbidity (that is foreign suspended matter) by this natural settling process is known as "sedimentation." Sedimentation is accomplished in settling tanks, where the water is held for a time to allow the floc to form and settle out turbidity.

In conventional treatment, settling immediately follows flocculation. The ideal detention period for settling after slow mixing is about 1 1/2 hours.

FILTRATION

Not all of the suspended matter is removed by sedimentation. Therefore, another process known as FILTRATION is used. An effective type of filter used in the filtration process is the DIATOMITE. Because it is lightweight, this filter is widely used at overseas bases. It removes suspended matter from water by passing it through a porous mat of diatomaceous silica. Diatomaceous silica is the skeletal remains of tiny algae, called diatoms, found in marine deposits that have been lifted above sea level.

The diatomite (also called diatomaceous earth or filter aid) is supported by a filter element. This supporting base is porous enough to permit maximum flow. It is also fine enough to support the filter cake that coats the element.

Diatomite filters are backwashed by reversing the flow of water and drawing filtered water through the filter to keep the filter output from falling off. The turbidity of the water is largely determined by the frequency of backwash.

DISINFECTION

Except in rare instances, all water supplies require disinfection. Disinfection is the chemical destruction of bacteria. Because of its economy, dependability, efficiency, and ease of handling, chlorine is almost always used for this purpose. The term *chlorination* generally means the same as DISINFECTION in waterworks practice.

Disinfection is a necessary step in ensuring a safe water supply. All new, altered, or repaired water-supply facilities must be disinfected before they are placed in service. Water from surface supplies may be disinfected before filtration or before coagulation and sedimentation to prevent the growth of organisms. This procedure is known as precholorination. The water must also be disinfected after filtration to destroy organisms that still remain and to provide a safeguard against recontamination. This procedure is known as postchlorination.

Chlorine is the disinfectant specified for Navy use. In the form of chlorine gas, or of hypochlorites which yield chlorine in water, chlorine is presently the only widely accepted agent that destroys organisms in the water and leaves an easily detectable residual that serves as an indicator of the completeness of treatment. The sudden disappearance of residual chlorine may signal contamination in the system. Under ordinary temperatures and pressures, chlorine gas is greenish yellow and is heavier than air. Its effectiveness as a disinfectant depends on the temperature and the hydrogen-iron concentration (pH) of the water to which it is added. Disinfecting action is faster at higher temperatures, but is retarded by pH. When the pH is above 8.4, the rate of disinfection decreases sharply.

Ozone, potassium permanganate, bromine, and iodine are also used to a limited extent as disinfectants. If excess lime is used for softening water, it makes the water alkaline and disinfects after about 10 hours of contact. However, the general applicability and economic advantage of chlorine have established it as the preferred disinfectant.

Chlorine Disinfectants

Chlorine disinfectants are available in a number of different forms as described in the following paragraphs.

LIQUID CHLORINE is liquified gas under pressure and is shipped in seamless steel cylinders under the regulations established by the Interstate Commerce Commission. The standard sizes of shipping containers are 150-pound cylinders, 1-ton containers, and 30-ton tank trailers.

Each pound of liquid chlorine produces about 5 cubic feet of chlorine gas at atmospheric pressure and at a temperature of 68 °F. A standard Chlorine Institute valve and a protective valve hood are screwed into the neck of each cylinder. The valve has a safety plug containing fusible metal that softens between 157 °F and 162 °F to protect the cylinder from bursting in case of fire. All cylinders must be factory tested every 5 years; 150-pound cylinders are tested at 500 pounds of pressure; and 1-ton containers are tested at 800 pounds of pressure.

HIGH-TEST CALCIUM HYPOCHLORITE is a relatively stable, dry granular solid or powder that is readily soluble to form a chlorine solution. Prepared under a number of trade names, including HTH, Perchloron, and Pittchlor, it is furnished in 3- to 100-pound containers and has 65 to 70 percent available chlorine by weight. Because of its concentrated form and ease of handling, calcium hypochlorite is preferred over other hypochlorites.

SODIUM HYPOCHLORITE is generally furnished as a solution that is highly alkaline, and therefore reasonably stable. Federal specifications call for solutions with 5 and 10 percent available chlorine by weight. Shipping costs limit its use to areas where it is available locally. It is also furnished as powder under various trade names, such as Lobax and HTH-15. The powder generally consists of calcium hypochlorite and soda ash that react in water to form sodium hypochlorite.

Ordinary household bleach is a sodium hypochlorite solution containing 2.5 percent available chlorine and is sometimes used at small installations.

CHLORINATED LIME, also known as CHLORIDE OF LIME or BLEACHING POWDER, is seldom used in water disinfection. It is a mixture of calcium chloride and calcium oxychloride that yields about 35 percent available chlorine when fresh. It deteriorates rapidly in a hot, moist atmosphere and should be purchased in small packages that can be kept sealed. Chlorinated lime contains an excess of insoluble lime; therefore, the solution should be prepared in a separate container, the lime permitted to settle, and the liquid decanted into a separate tank for use.

Useful Terms

When chlorine gas is introduced into pure water, some of it reacts to form hypochlorous acid, and the rest remains as dissolved chlorine. These forms of chlorine are termed *free available chlorine* because their oxidizing and disinfecting ability is fully available. Because most natural water contains small amounts of ammonia and nitrogenous organic substances, free available chlorine reacts with these substances to form chloramines and other complex chlorine-nitrogen compounds. These forms of chlorine compounds are termed *combined available chlorine*; part of the chlorine oxidizing disinfecting ability is lost. Both free available chlorine and combined chlorine react with oxidizable substances in water until their oxidizing and disinfecting ability is depleted. The amount of chlorine consumed in reacting with organic substances in water in a given time (usually 10 minutes) is called the CHLORINE DEMAND. Chlorine remaining in excess of the chlorine demand is the TOTAL CHLORINE RESIDUAL or RESIDUAL CHLORINE. Residual chlorine is composed of both free available chlorine and combined available chlorine. The time elapsing between the introduction of chlorine and use of the water is 30 minutes and is termed the *contact period*.

Bactericidal Effectiveness

The bactericidal effectiveness of chlorine depends upon the pH chlorine residual, contact period, and temperature. The pH value is a measure of the acidic or alkaline nature of the water. The pH of water is technically defined as the negative logarithm of the hydrogen in concentration. The pH value ranges from 0 to 14. A value of 7 is neutral. Values decreasing downward from 7 represent increasing numbers of hydrogen ions. Values increasing upward from 7 represent decreasing numbers of hydrogen ions. A low pH value indicates a very strong acid solution. A high pH value indicates a very strong alkaline solution. The alkalinity of water is the amount of "alkaline" substances in a given sample of water when titrating downward to a pH of 4.2 with sulfuric acid. The acidity of water is the amount of "acid" substances in a given sample of water when titrating upward to a pH of 4.2 with sodium carbonate. The pH value of natural water can vary from 3.4 to 9.0, depending on the impurities present in the water.

The pH influences the corrosiveness of the water, the amount of chemical dosages necessary for proper disinfection, and the ability of an analyst to detect contaminants. The pH scale is shown in figure 6-4.

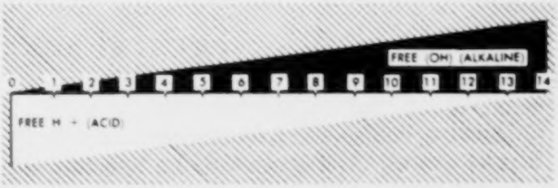

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Figure 6-4.—The pH scale.

Chlorine effectiveness increases rapidly with an increase in the residual. However, free available chlorine is 20 to 30 times as effective as combined chlorine under the most favorable conditions of pH (7.0) and water temperature (68 °F to 77 °F). Therefore, the relative amounts of free and combined available chlorines in the total residual are important.

Within normal limits, the higher the chlorine residual, the lower the required contact period. If the residual is halved, the required contact period is doubled. The effectiveness of free available chlorine at 35 °F to 40 °F is approximately half of what it is at 70 °F to 75 °F.

The effectiveness of free chlorine is highest at pH 7 and below. At pH 8.5, it is one-sixth as effective as at pH 7, and at pH 9.8, it may require 10 to 100 times as long for a 99 percent bacteria kill as at pH 7.

Points of Application

Plain or simple chlorination is the single application of chlorine as the only treatment before discharge to the distribution system, as in the chlorination of groundwater supplies and previously unchlorinated purchased supplies. Prechlorination is the application of chlorine to raw water before coagulation, sedimentation, or filtration. Postchlorination is the application of chlorine after filtration, but before the water leaves the treatment plant. Rechlorination is the application of chlorine into the distribution system or into a previously chlorinated purchased supply to maintain the chlorine residual.

The above applications are normally continuous. Very heavy chlorination for a limited period is sometimes applied at specific points in the distribution system to destroy localized contamination.

Other Uses of Chlorine

Chlorine is also used to control tastes and odors in water. It reacts with the substances causing taste and odor, such as hydrogen sulfide, minute organisms, algae, and organic compounds. If the reaction is incomplete, the taste and odor of some substances may be intensified or become more objectionable. Chlorine is also used to a limited extent to oxidize iron and manganese and to remove color.

Safety

Safety is important in the handling of chlorine. Some of these important factors are as follows:

- Provide self-generating oxygen-breathing apparatus or self-contained oxygen-breathing apparatus designed to cope with chlorine.
- Maintain only the supply of chlorine in any chlorinator room that will do for normal daily demands. Store the main supply in a detached noncombustible building or in a fireproof room that is vented only to the outside and separated from the main part of the building. Keep the chlorinator and chlorine storage building or rooms locked to prevent the entrance of unauthorized personnel and restrict these areas from any other use.
- Allow only reliable and trained personnel to handle chlorine.
- Handle containers carefully to avoid dropping or bumping them.
- Avoid hoisting containers much as possible; if hoisting is necessary, use safe lifting clamps.
- Store cylinders in a cool place, away from dampness, steam lines and fire, and in an upright position secured from tilting and falling.
- Keep protective valve caps on containers when not in use; never tamper with safety devices on containers.
- Never connect a full cylinder to a manifold with another cylinder unless the temperatures of both are nearly the same.
- When not withdrawing chlorine or when cylinders are empty, keep the valves closed.
- Disconnect the valves as soon as the containers are empty, and check for chlorine leaks

at the valve outlets. Test for leaks by passing an opened bottle of strong ammonia solution around the valve. White fumes of ammonium chlorine will appear if there is any leakage. Leaks around fittings, connections, and line can be detected in the same way. Do not apply ammonia solution to plated metal parts as it will remove the plating.

- When chlorine is noticed, workers should avoid panic, refrain from coughing, keep mouth closed, avoid deep breathing, keep head high, and withdraw at once from the affected area. Only qualified personnel with suitable respiratory equipment should be assigned to investigate and correct the cause of chlorine leaks. If chlorine is being discharged, close the container valve immediately. If chlorine is escaping in liquid form, turn the containers so the chlorine escapes as gas. This will reduce leakage. Do not apply water to the leak; this dangerous practice causes corrosion that may increase the leakage. Electronic chlorine gas detectors are widely used in plants today.

- The handling of a persistent chlorine leak in a plant is best left to the chlorine supplier.

- Never apply a flame, blowtorch, or other direct heat to chlorine containers; discharge them in a room with a temperature of about 70 °F.

- Never ship a defective or leaky cylinder unless it is completely empty. Paint "DEFECTIVE" plainly on all such cylinders.

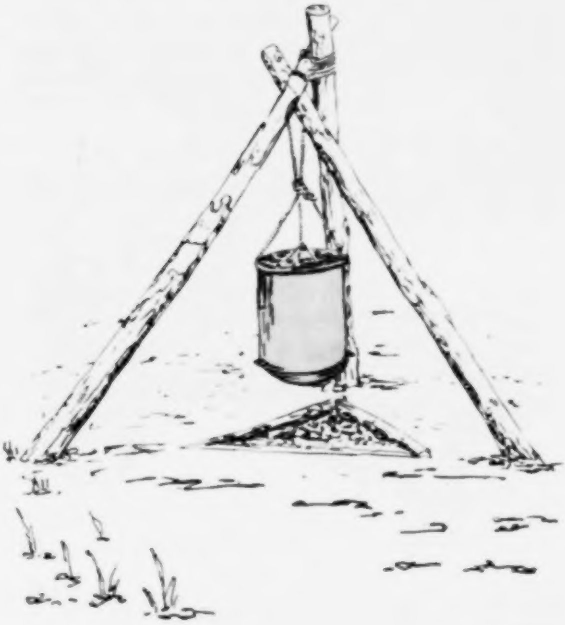
- Follow all regulations on shipping, storing, and using compressed gas cylinders.

- Provide proper means of exit from areas where chlorine is stored or used.

- Never use a chlorine cylinder except to hold chlorine gas.

TYPES OF PURIFICATION UNITS

At overseas bases, you will find portable purification equipment which can be moved from place to place, as required. This equipment usually consists of comparatively small units. When you need more water than one small unit can produce, then two or more units may be used. Some of the types of purification units which you will be likely to use are discussed in the following subsections.



54.87

Figure 6-5.—Lyster bag.

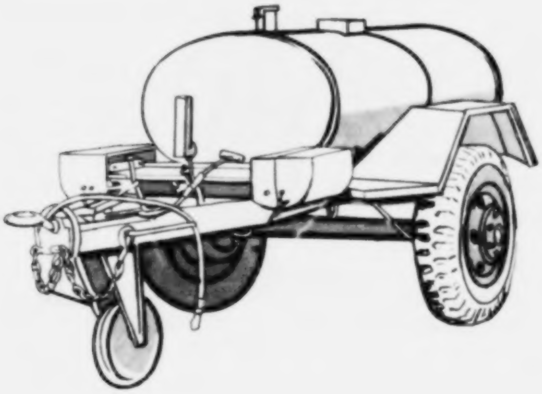
LYSTER BAG

A Lyster bag (fig. 6-5) is primarily a dispensing unit for purified or distilled water. These bags are sturdy, watertight, and readily collapsible for packing. Water is withdrawn through small faucets at the bottom. When no other purification equipment is available, a Lyster bag can be used to disinfect raw water. Normally, chemical kits for purification are supplied with each Lyster bag. When you have to use a Lyster bag, follow the treatment instructions supplied by the manufacturer of the unit.

TANK TRAILERS

Tank trailers, like Lyster bags, are designed primarily as dispensing units for purified or distilled water. However, tank trailers can be used to disinfect raw water, when necessary. The water is treated as directed by local medical authorities.

A tank trailer holds approximately 300 gallons of water. (See fig. 6-6.) The unit comes equipped with faucets for dispensing the water. When desirable, water can be transferred from the tank trailer into a Lyster bag. The Utilitiesman should make sure the tank trailer has been properly cleaned and disinfected before filling it with water.



54.88

Figure 6-6.—Tank trailers.

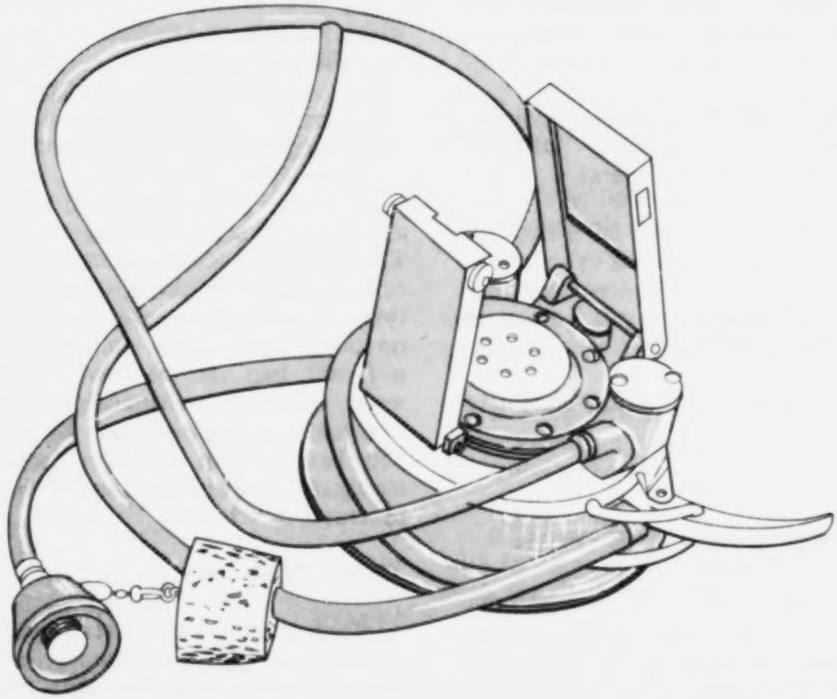
KIT-TYPE PURIFICATION UNIT

Another important piece of equipment is a hand-pumping kit-type purification unit (fig. 6-7) that has been designed for the use of small, isolated troop units. It can be used by initial landing units, patrols, parachute troops, or stranded personnel. This unit is durable and easy to operate. It produces clear filtered water from turbid raw water at the rate of 1/4 gpm. It also reduces the bacteria concentration in the water.

Major Parts

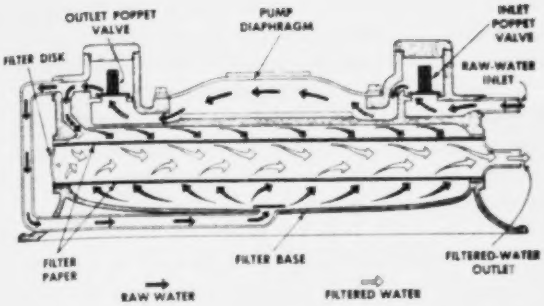
This unit is about 6 inches in diameter and 3 inches in height. It has a small hand-operated diaphragm pump, double-faced filter disk, base-clamping ring, and suction and discharge hoses.

The raw water is drawn by the diaphragm pump through the suction strainer and hose. It enters the unit and is forced through the filter pads



54.436

Figure 6-7.—1/4-gpm water purification unit assembled.



54.89

Figure 6-8.—Flow diagram of water through the kit-type purification unit.

on the top and bottom of the filter disk (fig. 6-8). The filtered water then flows to the discharge hose.

Assembly and Operation

You will find it easy to assemble and operate the unit. First, remove the filter disk from the pump and base by releasing the clamping ring catch. Place a filter pad on top of the base; put the filter disk carefully on the pad, and then lay another filter pad on top of the disk. Be sure to keep everything clean and to place the smooth side of the filter pads against the disk.

The diaphragm pump is put on top of the filter disk, and the three parts (base, disk, and pump) are clamped together. If the clamp is too tight or too loose, adjust the clamping ring at the hinge.

After you finish this assembling procedure, check the suction hose to ensure it is connected tightly to the unit. Then put the suction strainer in the water so it is able to take in water without being clogged by leaves or moss.

Now you are ready to filter raw water. Work the pump level at the rate of 70 to 80 strokes per minute. If no water is delivered after 1 or 2 minutes, check the strainer and suction hose for clogging or a loose connection to the pump. Also, check the poppet valve caps for leaks.

The water flows through the filters and the discharge hose, and you can catch it in canteens or other containers. You are not ready to drink this water yet, because it must first be disinfected with iodine tablets.

When the flow of water from the discharge hose gets too small, it is time to change the filter pads. Usually, a filter pad set filters at least 20 quarts of water.

Under the hinge of the pump lever is a small pressure-relief valve. This opens and discharges water if you pump too fast and the water pressure against the filter disk is too high. Slow down the pumping rate to prevent opening of the pressure-relief valve.

1,500-, 3,000-, and 10,000-GPH WATER PURIFICATION UNITS

In the field you may also use the continuous flow, or erdlator type of water purification unit. The continuous flow type of equipment is designed for continuous purification of natural raw water by the suspended solids contact method of water treatment. Water enters, is treated, and leaves the equipment at a constant rate of flow, 24 hours a day if necessary; thus its operation is called "continuous flow."

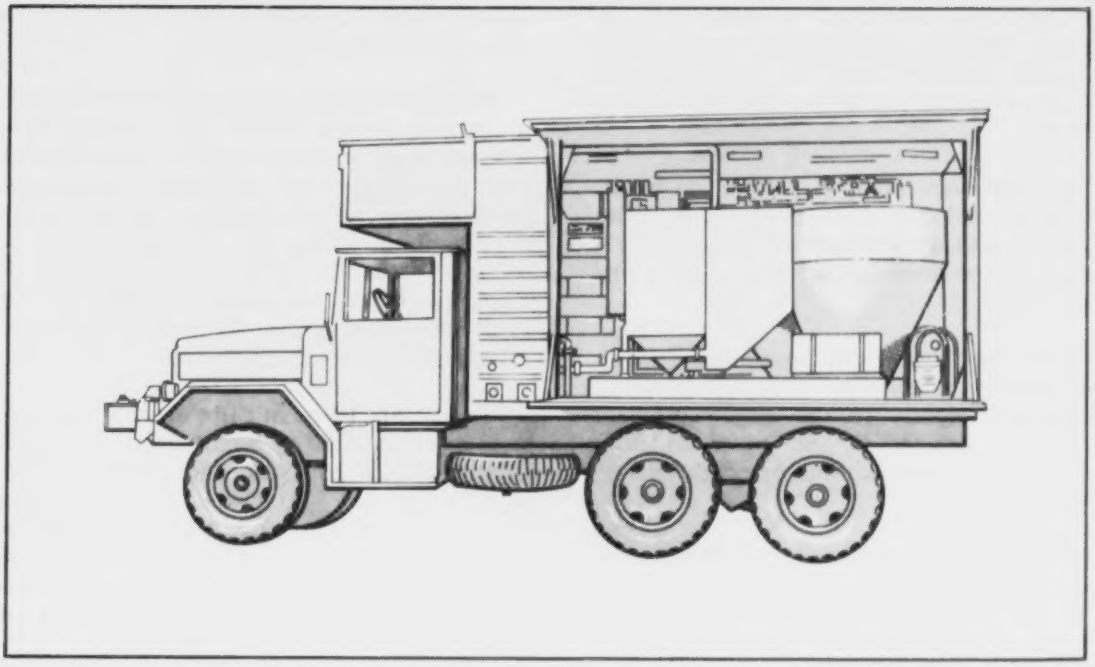
All models contain a tank, an influent launder, an effluent launder, a wet well, a sludge concentrator tank, a slurry weir box, a downcomer tube, an agitator shaft with disks, an agitator speed reducer, a drive motor, an air pump, an aluminum base, and bridge rails. The erdlator assembly reduces the content of the organic and suspended matter of the water and produces an effluent suitable for application to the diatomite filter.

These units come in three sizes: a van-type body-mounted, 1,500-gph unit; a van-type body-mounted, 3,000-gph unit; and a semiportable, knockdown-type, 10,000-gph unit. All units are constructed and operated in a similar manner, except the erdlator tank of the 10,000-gph unit is constructed in three sections while each of the other two units have a one piece tank.

The water purification unit, van-type body-mounted, 1,500-gph, consists of water purification equipment installed inside an insulated and heated van body (fig. 6-9). The heated van body contains the chemical feed equipment, the coagulator assembly, the filter section (one filter), the electrical control cabinet, and the necessary piping, valves, and control equipment. Supporting equipment furnished with the water purification unit (WPU) includes a standard 2 1/2-ton truck chassis on which the van body equipment is mounted; a 10-kW engine generator set, mounted on a standard towed-type 1 1/2-ton cargo trailer; two 1,500-gallon collapsible fabric water storage tanks; three portable centrifugal pumps, two electrically driven and one gasoline-driven engine; a 5-day supply of chemicals; and the necessary hose assemblies.

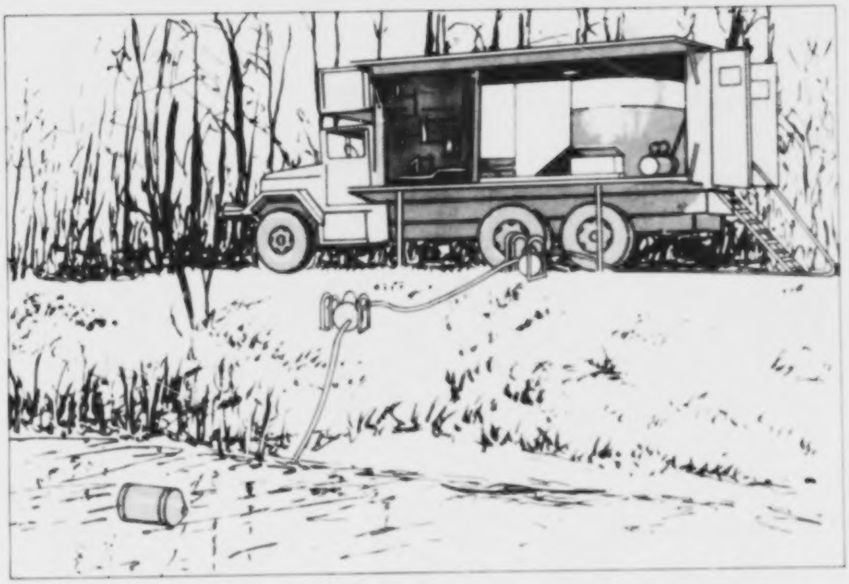
The water purification unit, van-type body-mounted, 3,000 gph, consists of water purification equipment installed inside an insulated and heated van body (fig. 6-10). The heated van body contains the chemical feed equipment, the coagulator assembly, the filter section (two filters), the electrical control cabinet, and the necessary piping, valves, and control equipment. Supporting equipment furnished with the erdlator includes a standard 2 1/2-ton truck chassis on which the equipment is mounted; a 10-kW engine generator set mounted on a standard towed-type 1 1/2-ton cargo trailer; two 3,000-gallon collapsible fabric water storage tanks; three portable centrifugal pumps, two electrically driven and one gasoline-driven engine; a 5-day supply of chemicals; and the necessary hose assemblies.

The 10,000-gph WPU consists of a 14-foot-diameter coagulator assembly, chemical solution feeders, slurry feeders, two gravity-type rapid sand filters, a raw-water pump, a distribution pump, and a filter backwash pump. The other facilities and equipment required for operation include a gasoline engine-driven generator; a raw-water booster pump; a high-pressure distribution pump; a 250-barrel raw-water storage tank; a 250-barrel backwash storage tank; a 500-barrel distribution water storage tank; a 40- by 40-foot prefabrication warehouse type of building; 4-inch Victaulic couplings, pipe fittings, and valves; and chemical supplies. A typical equipment layout is shown in figure 6-11.



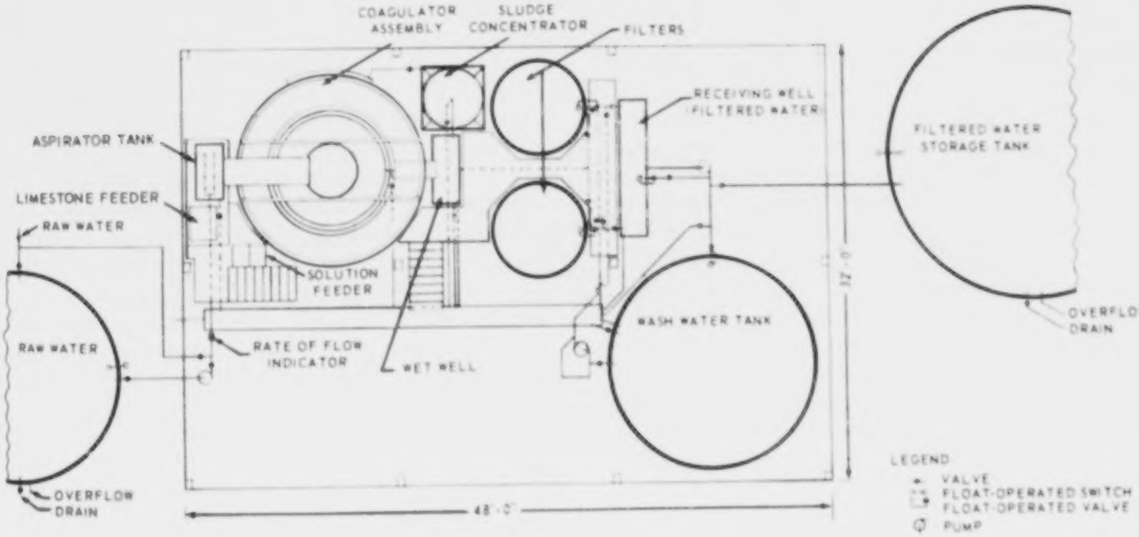
54.437

Figure 6-9.—Water purification unit (erdlator) van-type body mounted, 1,500 gph.



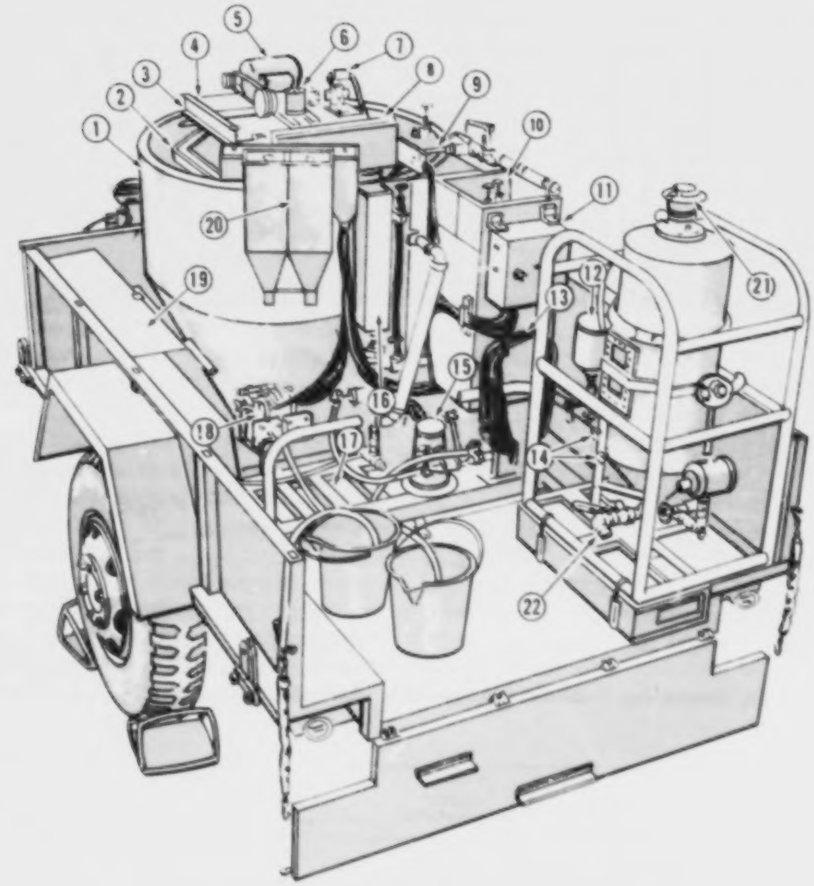
54.438

Figure 6-10.—Water purification unit (erdlator) van-type body mounted, 3,000 gph with pumps connected in series.


COAGULATOR ASSEMBLY
SLUDGE CONCENTRATOR
FILTERS
RECEIVING WELL (FILTERED WATER)
FILTERED WATER STORAGE TANK
ASPIRATOR TANK
LIMESTONE FEEDER
RAW WATER
SOLUTION FEEDER
RAW WATER
RATE OF FLOW INDICATOR
WET WELL
WASH WATER TANK
OVERFLOW DRAIN
32'-0"
OVERFLOW DRAIN
48'-0"
LEGEND
VALVE
FLOAT-OPERATED SWITCH
FLOAT-OPERATED VALVE
PUMP

54.439

Figure 6-11.—Typical layout of 10,000-gph water purification unit.



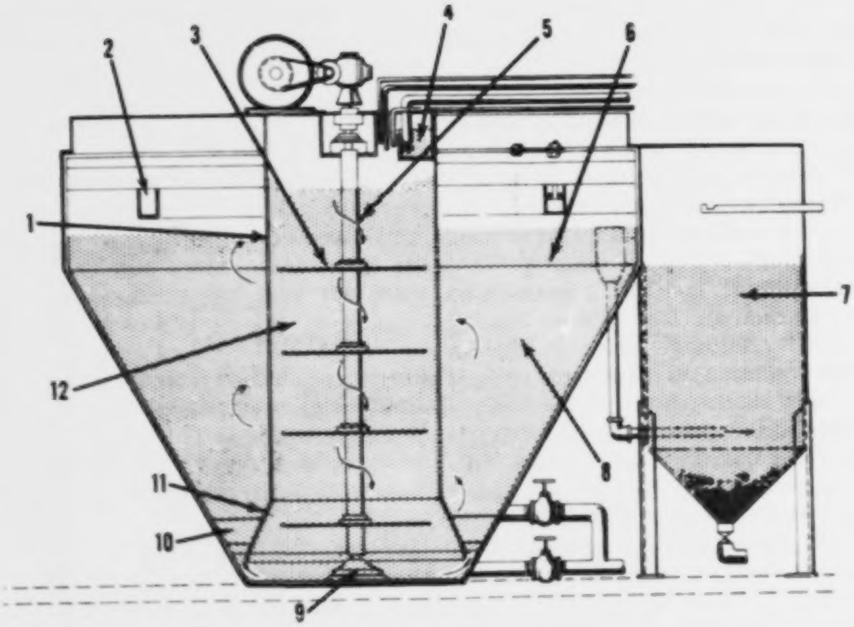
1. Erdlator tank.
2. Effluent launder.
3. Effluent launder leveling rods (3 rqr).
4. Bridge rails.
5. Agitator drive motor.
6. Speed reducer.
7. Air pump.
8. Influent launder.
9. Wet well tank.
10. Sludge concentrator tank.
11. Electric control box.
12. Precoat funnel.
13. Power cable.
14. Pressure gauges.
15. Filter pump.
16. Weir box.
17. Erdlator mounting base.
18. Chemical solution feeder.
19. Storage box.
20. Chemical slurry feeder.
21. Air release valve.
22. Flow controller valve.

87.15

Figure 6-12.—Water purification unit mounted in trailer.

Erdlator Assembly

The erdlator tank (1, fig. 6-12) is a circular funnel-shaped unit of one-piece aluminum construction. A stub shaft and bearing support for the agitator are mounted in the bottom of the tank. There is a ring near the bottom secured to the tank with a series of short baffles that support the downcomer tubes. A drawoff port is located opposite the weir box (16) and another near the top which opens into the wet well tank (9). There are two drains, an upper one for partial draining and a lower one for complete draining. The erdlator tank serves as a separator that hydraulically separates the slurry blanket from the clear water in the upper section of the tank in



1. Downcomer tube.
2. Effluent launder.
3. Circular disk (4 rqr).
4. Influent launder.
5. Agitator shaft.
6. Separator zone.
7. Sludge concentrator tank.
8. Clarification zone.
9. Bearing support.
10. Baffle.
11. Baffle ring.
12. Mixing zone.

87.17

Figure 6-13.—Cross section of an erdlator.

what is termed the *separator zone* (6, fig. 6-13). It also serves as a clarifier as the flow of coagulated water is directed in an upward rotation direction into the clarification zone (8).

The influent launder (8, fig. 6-12) is of one-piece aluminum construction and is attached to the two bridge rails. The raw water is introduced into the influent launder, through the aspirators, from where it overflows into the downcomer tube or mixing zone.

The effluent launder (2, fig. 6-12) is a one-piece hexagon-shaped aluminum trough that surrounds the downcomer tube (1, fig. 6-13). It is attached to the bridge rails (4, fig. 6-12) by three leveling rods (3). It collects the clear water from the upper section of the erdlator tank and discharges it into the wet well tank (9).

The wet well tank (9, fig. 6-12) is made of aluminum and consists of a triangular section welded to the rear quadrant of the erdlator tank for the collection of the effluent from the erdlator. It provides for limited storage of coagulated water and serves as a sump for the suction of the filter pump. It contains an overflow pipe to permit operation of the erdlator at rated capacity when the filter is stopped. A drain in the bottom of the wet well permits complete drainage of the tank to waste when water unsuited for filtering is obtained from the erdlator.

The sludge concentrator tank (10, fig. 6-12) is welded externally to the rear of the wet well tank. It is a square funnel-shaped aluminum tank with a shorter circular tank welded to its inside. There is an inlet in the side of the main tank near the bottom that permits the flocculent slurry to enter by gravity. The inner tank has an opening in the bottom controlled by a manually operated plug valve to permit intermittent drainage of slurry to waste. There is an outlet near the top of the main tank with a manually operated valve to control the flow of clear coagulated water to the wet well. There is also an outlet in the bottom for draining the tank.

The slurry weir box (16, fig. 6-12) is a small aluminum tank welded externally to the erdlator tank. It houses the drawoff port near the top of the erdlator tank and permits gravity flow of flocculent slurry from the erdlator tank to the sludge concentrator tank.

The agitator consists of a tubular agitator shaft (5, fig. 6-13) with four equally spaced circular disks (3) attached. It is mounted in the center of the erdlator tank on the bearing support (9). The agitator is surrounded by the downcomer tube (1) and baffle ring (11) to form the mixing zone (12).

The speed reducer (6, fig. 6-12) is mounted on two spacers attached to the agitator bearing mounting plate. It reduces the drive speed from the agitator drive motor (5) to the erdlator agitator drive shaft.

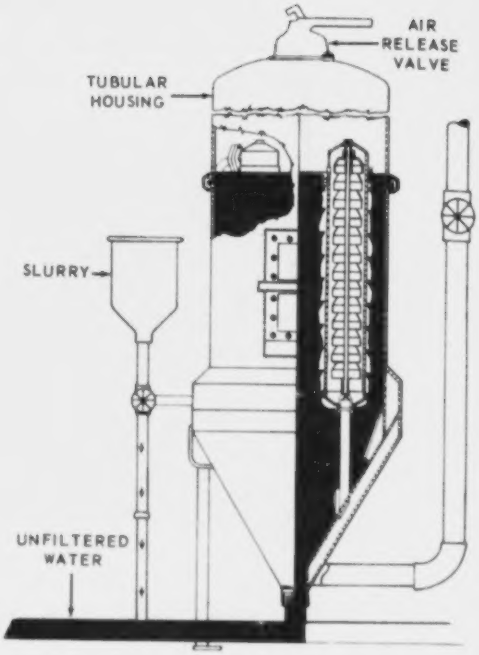
The agitator drive motor (5, fig. 6-12) is mounted on a bracket attached to the bridge rails (4). It is a single-phase, totally enclosed motor with oblong mounting holes in the base for use in adjusting the drive belt. The agitator drive motor also drives the air pump (7).

The air pump (7, fig. 6-12) is an oilless type with an intake filter. It is mounted to the bearing mounting plate and driven off an extended shaft from the speed reducer (6). It is used to furnish air to the duplex chemical slurry feeders.

The bridge rails (4, fig. 6-12) consists of two aluminum channels attached to the top of the erdlator tank (1). They are used for supporting components of the erdlator located over the tank.

The filter section is mounted in a tubular housing (fig. 6-14) and consists of a filter specifically designed to use diatomaceous earth. A filter pump (15, fig. 6-12) is used for pumping the coagulated water through the filter. There are two pressure gauges (14, fig. 6-12) for indicating the pressure on the effluent and influent sides of the filter. A precoat funnel (12, fig. 5-12) is used for adding prepared diatomite slurry for precoating of the filter elements. There is also an air release valve (21, fig. 6-12) for releasing air trapped in the filter. The flow controller valve (22, fig 6-12) is used for maintaining a fixed constant rate of flow through the filter, and additional valves and piping are necessary for the operation of the filter.

The chemical slurry feeder (20, fig. 6-12) is an aluminum tanklike unit, mounted to brackets welded to the erdlator tank. It has two identical chemical compartments and water collection troughs, and two weirs, one of which contains a float-operated needle valve. One compartment supplies pulverized limestone slurry (coagulant aid) and activated carbon to the mixing zone of the erdlator, and the other supplies diatomite slurry to the suction inlet of the filter pump. A timer dial is mounted on the lower part of the feeder.



54.440
Figure 6-14.—Flow diagram during precoating process of a diatomite filter in continuous flow unit.

The chemical solution feeder (18, fig. 6-12) is constructed of material having anticorrosive resistance and is mounted on the erdlator mounting base (17). It consists of two diaphragm pumps operated from one electric motor by means of a gear reduction mechanism. The chemical solution feeder pumps ferric chloride and calcium hypochlorite solution from two rubber pails into the mixing zone or downcomer tube (1, fig. 6-13) of the erdlator.

The filter pump (15, fig. 6-12) and the raw-water pump are identical. Both pumps are centrifugal, vertical-type, powered by a self-contained integrally built universal motor. The raw-water pump is used for pumping the raw water to the erdlator. It is mounted in a tubular frame designed to mount on the erdlator base when the pump is not in use. The filter pump is used for pumping coagulated water from the wet well tank to the filter. It is mounted on the erdlator mounting base (17).

The distribution pump is a centrifugal-type, gasoline-driven engine, mounted in a tubular frame. It is used to distribute the filtered water to the user.

The electric control box (11, fig. 6-12) is mounted on the front of the sludge concentrator tank (10). It contains the circuit breakers, transformer, receptacles, switch, signal lamp, alarm buzzer, and the necessary controls and wiring to operate the components of the water purification unit.

Two collapsible, synthetic rubber-coated nylon tanks are furnished with the basic issue items. Each tank has a capacity of 500 gallons. However, different type tanks may be used as required. These tanks provide storage for the filtered water.

A gasoline engine generator is furnished with the basic issue items. The generator is capable of providing all the electrical power required for the operation of the water purification unit.

Sufficient hoses and fittings are furnished with the basic issue item to equip the water purification unit for pumping raw water from the source to the erdlator, filtered water from the filter to the storage tanks, finished water from the storage tank to the user, and wastewater from the erdlator and filter to waste.

The unit is equipped with piping and valves of four different colors: black, indicates raw water; yellow, coagulated water; red, wastewater; and green, filtered water.

Operation of Erdlator Tank

Raw water is pumped directly from the source into the erdlator tank. It is introduced at the top of the tank into the influent launders through the aspirators that aerate the raw water. The water overflows from the influent launders into the mixing zone where chemicals are added, such as ferric chloride, pulverized limestone, and calcium hypochlorite. When activated carbon is needed for a special purpose, such as decontamination or taste and odor control, it is also added here. Note that the coagulation (pH) test is not used when continuous flow equipment is used.

As the water and chemicals descend through the mixing zone, they are thoroughly mixed by the motion of four flat circular disks located at equal intervals on the rotating agitator shaft at the center of the tank. This flow is a downward rotation. Shallow baffles that deflect the flow and start it in a counterrotation are at the bottom of the tank.

The baffles direct the water into the clarification zone, the slant-sided area that surrounds the mixing zone. It is forced upward in a counterrotation at a reduced speed but continues with sufficient velocity to keep the slurry volume, together with the clear water above the slurry pool, rotating. The coagulants draw the solids into increasingly large particles which, because of their weight, tend to rise more slowly than the clear water that goes to the top of the clarification zone. These actions taking place in the mixing zone and the clarification zone illustrate the terms *solid contact* and *upward flow* used to describe the continuous flow water purification units.

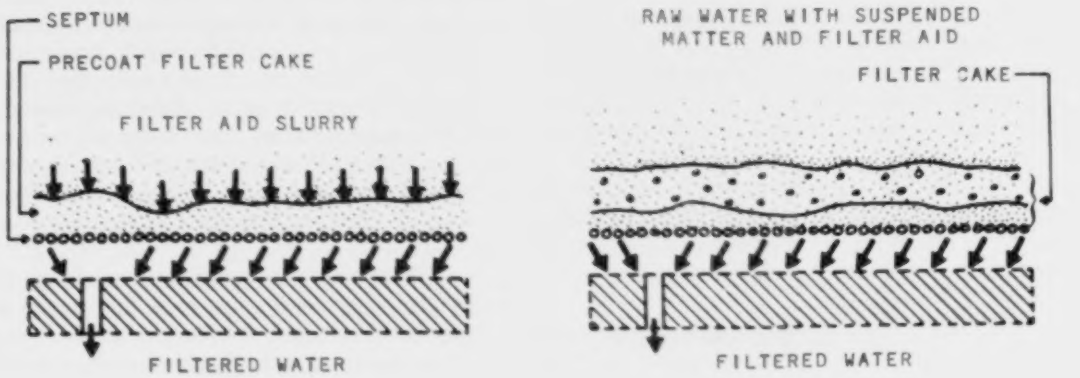
There is a distinct separation of the clear water in the separator zone and the slurry in the clarification zone. At the top of the separator zone, the clear water is collected by the effluent launder and is continuously drawn off and discharged into the "wet well" tank. There it is stored until it is delivered into the filter. Besides providing storage space for clarified water, the wet well tank also acts as a sump for the suction of the filter pump.

The sludge concentrator tank is attached externally to, and at one quadrant of, the coagulator. The sludge concentrator tank functions as a small auxiliary coagulator. It draws slurry, still in the flocculent stage, from the clarification zone, and provides a longer holding period for slurry concentration than does the clarification zone itself. The sludge concentrator tank also permits settling of sludge to the bottom of the tank for continuous or intermittent drainage to waste and skimming of clear, coagulated water at the top of the tank for return to the wet well.

So far, the water has been subjected to the processes of coagulation, sedimentation, and chlorination by one continuous flow process. Further purification of the water is necessary. Remaining solids must be removed by filtration. The diatomite system causes the water to be forced through a layer of diatomaceous earth and serves to remove the remaining suspended impurities.

Properly operated, diatomite filters are capable of removing from coagulated and settled water amoebic cysts, the cercariae of schistosomes, and approximately 90 percent of the bacteria, as well as producing water with less than one unit turbidity. One type of filter, the "ND 25," is shown in figure 6-14.

A slurry of diatomite and water is introduced into the filter to precoat the system before the filter is put into operation. The diatomite is held and supported on the filter element (fig. 6-15) by the flow of water into the filter unit. During the filtering process (fig. 6-16), the porosity of the filter cake is maintained by the continuous addition of a small amount of diatomite slurry. When the pressure required to pump water through the filter increases, it indicates that the filter is clogging and backwashing is necessary. To


SEPTUM
PRECOAT FILTER CAKE
FILTER AID SLURRY
FILTERED WATER
RAW WATER WITH SUSPENDED MATTER AND FILTER AID
FILTER CAKE
FILTERED WATER

1. CROSS SECTION VIEW

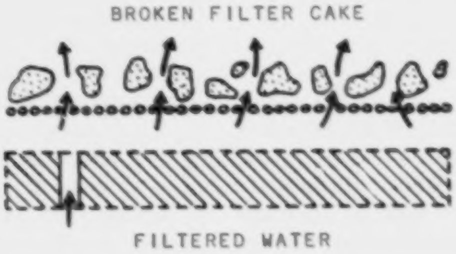
DURING PRECOATING

FLOW OF FILTER AID IN SUSPENSION IS GREATEST THROUGH THINNEST PORTION OF FILTER CAKE, BUILDING UP THAT PORTION AND RESULTING IN UNIFORM COATING OF FILTER AID OVER ENTIRE ELEMENT.

2. CROSS SECTION VIEW

DURING FILTERING

POROSITY OF THE FILTER CAKE IS MAINTAINED UNDER PRESSURE BY RIGID PARTICLES OF FILTER AID MIXING WITH COMPRESSIBLE PARTICLES OF SUSPENDED MATTER IN RAW MATTER.


BROKEN FILTER CAKE
FILTERED WATER

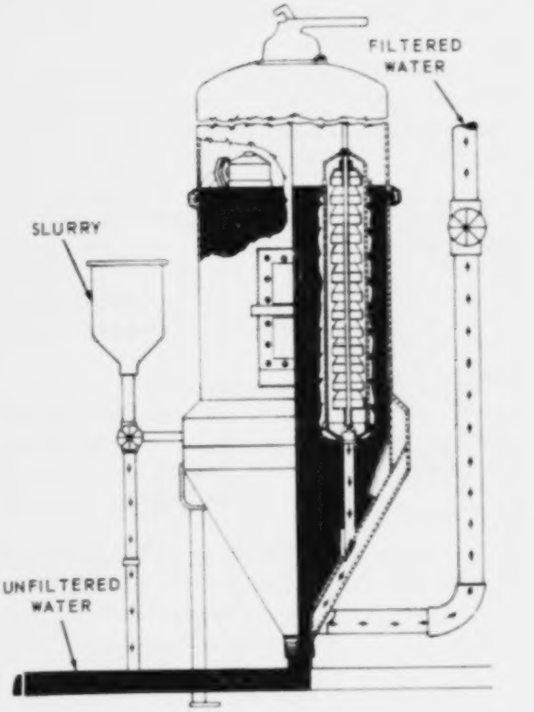
3. CROSS SECTION VIEW

DURING BACKWASHING

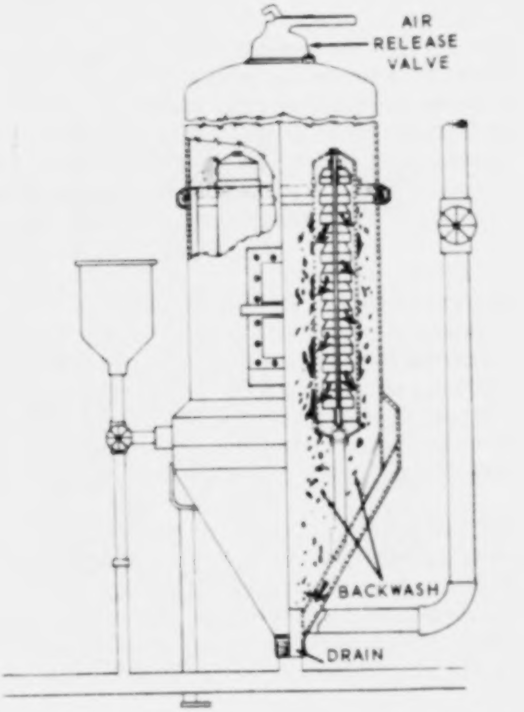
COMPRESSED AIR HELD BY WATER PRESSURE IS RELEASED FROM CUPS WHICH CAUSES WATER TO FLOW SUDDENLY IN A REVERSE DIRECTION, THEREBY BREAKING UP THE FILTER CAKE.

54.441

Figure 6-15.—Operation of filter element.



54.440.1
Figure 6-16.—Flow diagram-production of filtered water through diatomite filter of continuous flow unit.



54.440.2
Figure 6-17.—Flow diagram-backwash cycle during operation of diatomite filter continuous unit.

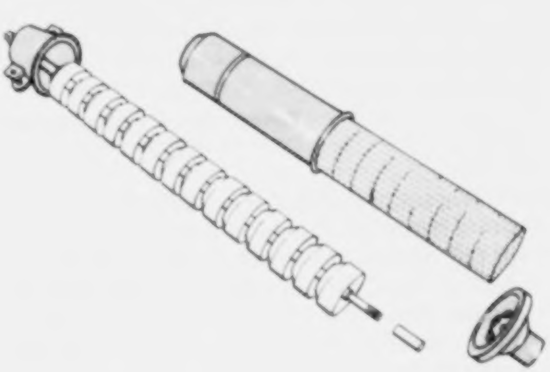


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Figure 6-18.—Filter element disassembled, showing plastic cups and plastic cover rolled back.

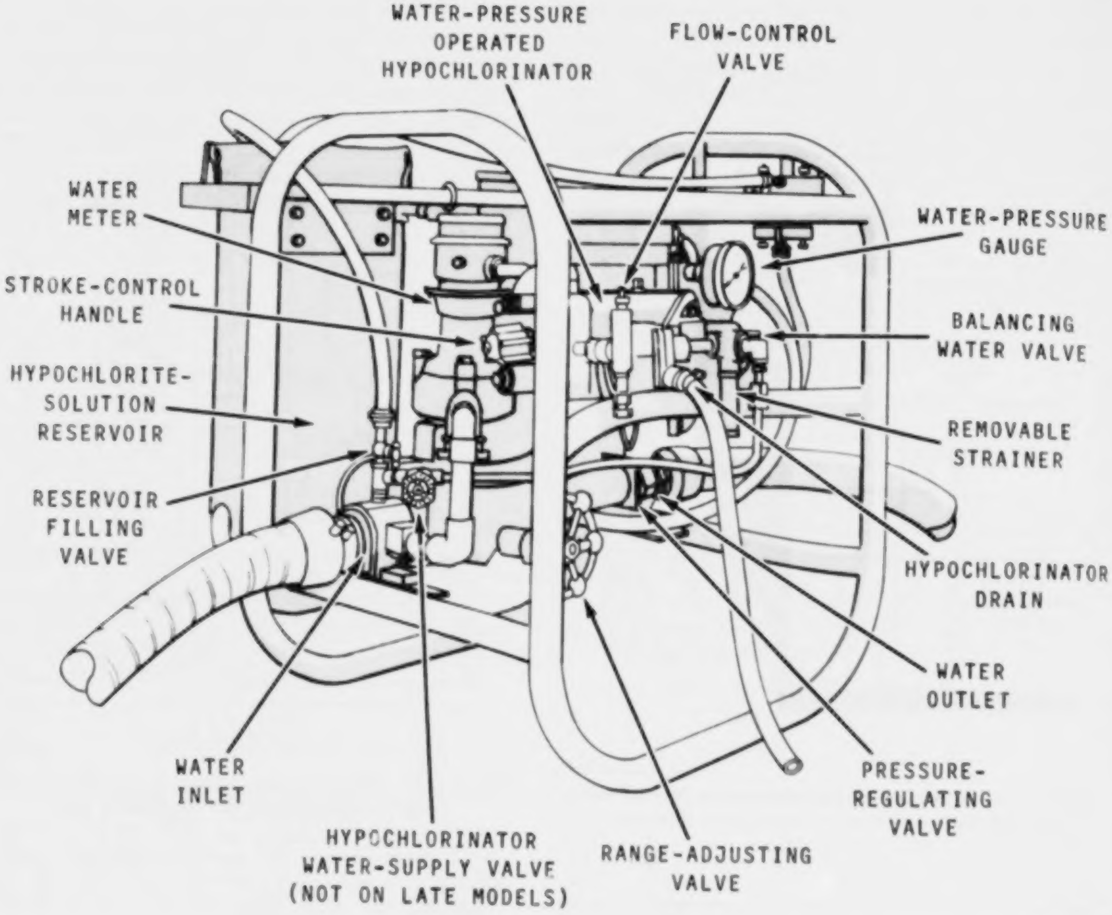
backwash the filter, you open the air release valve (fig. 6-17). The air pressure under the filter dome is then suddenly released, allowing the air in the filter element air traps to expand with the effect of a blast that knocks the diatomite and foreign matter off the filter elements (fig. 6-18). This is called backwashing by the air pump method. After the filter has been backwashed and drained, the filter pump should then be used to flush the filter before the unit is again precoated and put back into operation.

Maintenance and Repair

As a Utilitiesman, it is your duty to ensure the water purification unit is ready for operation at all times. To be in serviceable condition, it must be inspected periodically, so defects can be detected and corrected before they result in serious damage or failure.

HYPOCHLORINATION UNITS

Hypochlorination units are major water treatment items and are widely used at large overseas bases. They are designed to chlorinate water automatically. This is important where the water requires only chlorination and the rate of flow of the water being treated is likely to vary.


WATER-PRESSURE OPERATED HYPOCHLORINATOR
FLOW-CONTROL VALVE
WATER METER
WATER-PRESSURE GAUGE
STROKE-CONTROL HANDLE
BALANCING WATER VALVE
HYPOCHLORITE-SOLUTION RESERVOIR
REMOVABLE STRAINER
RESERVOIR FILLING VALVE
HYPOCHLORINATOR DRAIN
WATER OUTLET
WATER INLET
PRESSURE-REGULATING VALVE
HYPOCHLORINATOR WATER-SUPPLY VALVE (NOT ON LATE MODELS)
RANGE-ADJUSTING VALVE

29.233 (54)

Figure 6-19.—Portable automatic hypochlorination unit (left front view).

The unit issued to overseas bases is complete with a bypass fitting set and has a capacity of 2 to 100 gpm when installed in the line and a capacity of 2 to 400 gpm when installed as a bypass. (See fig. 6-19.) It is used where the raw-water supply is clear and found to be free from harmful amoebic cysts.

The unit is usually mounted on a pipe frame with skids. Its main parts are a hydraulically operated hypochlorinator, a water meter, a manual range-adjusting valve, and a pressure-regulating valve.

The hypochlorinator pumps the hypochlorite solution into the water at a rate governed by the speed of the water meter. The water meter is operated by a small flow of water diverted from the main line by means of the manual range-adjusting valve. The pressure-regulating valve maintains water pressure in the system of at least 10 pounds per square inch, so the hypochlorinator can be operated satisfactorily.

Operating Procedures

Before starting the hypochlorination unit, you should check it for any damage or leakage. Also ensure there is an adequate supply of hypochlorite solution in the reservoir. If necessary, make up some new solution.

For a new solution, high-test hypochlorite powder is added to clear water in the solution reservoir. When the maximum flow to be treated is near 100 gpm, add 10 ounces of hypochlorite powder to 5 gallons of water. If you anticipate a maximum flow of 50 gpm, add 5 ounces to 5 gallons of water. If extra chemical is left, be sure you store it in a dry, airtight container.

Now check the end of the hypochlorinator suction hose to see that the strainer is installed. Place the hose in the solution reservoir, so the strainer is at the bottom of the reservoir.

Your operating duties will be mostly adjusting valves. Set the hypochlorinator stroke control handle at 10 on the dial. Open wide the hypochlorinator water-supply valve and the manual range-adjusting valve.

Check to see that the water pressure gauge on the hypochlorinator registers at least 10 pounds per square inch. See that the flow-controller needle is open about three-quarters of a turn from its dead shutoff position.

Adjust the range-adjusting valve so the hypochlorinator runs at a speed of 12 strokes per minute when the maximum flow is reached. The maximum flow should not exceed 100 gpm.

Check to see that the hypochlorinator is primed. When properly primed, the hypochlorite solution should spurt into the sight glass during every suction stroke of the hypochlorinator. Usually the machine is self-priming. The air vent on the sight glass must be closed when the hypochlorinator is running. If the unit cannot be primed, check the hypochlorinator suction line for air leaks.

After you have performed these operations, you have little to do in operating the unit. Your primary duty is to make up a new batch of hypochlorite solution whenever the level in the reservoir drops to within 2 or 3 inches of the strainer.

There are two things to consider in determining the amount of chlorine to be added to the water: one is the volume of hypochlorite solution used and the other is the strength of the solution. For example, 60 gallons of 0.5 percent hypochlorite solution contains the same amount of chlorine (2.5 pounds) as 30 gallons of 1 percent solution.

If the volume of water being treated requires 2.5 pounds of chlorine per day, you may use either the 60 gallons per day of 0.5 percent hypochlorite solution or the 30 gallons per day of 1 percent solution.

At a speed of 12 strokes per minute, the hypochlorinator pumps 60 gallons of solution per day when the stroke control handle is set at 10 on the dial. In general, it is more desirable to operate the hypochlorinator with a weak solution and a long stroke instead of a strong solution and a short stroke. In the example given, the 0.5 percent solution is preferable.

When the water used to mix the sterilizing solution contains "hardness," it is advisable to add some soda ash to the solution. This results in the precipitation of the hardness, and the precipitate should settle to the bottom of the reservoir. The amount of soda ash to use is best determined experimentally by observing the precipitate.

The shutdown of the unit is more or less automatic because the hypochlorinator stops when the water stops flowing through the main under treatment. Remove the hypochlorinator suction hose and strainer from the solution reservoir when you take the unit out of operation.

When the unit is to be removed for storage or shipment or is to be exposed to freezing temperatures, all water must be drained from the hypochlorination unit. It is particularly important that all of the solution is drained from the hypochlorinator pumping block by removing the pumping block and poppet valves. The sight glass and solution reservoir should also be drained.

Maintenance and Repair

There is little to do regarding maintenance of the unit. No lubrication is required for this unit. While the machine is running, check the water pressure gauge and the sight glass frequently. The pressure should not be less than 10 pounds. You should be able to see the solution spurt into the sight glass on every suction stroke of the hypochlorinator. At the first sign of failure, stop the unit and locate and correct the trouble.

Every few hours, check to see that there is an adequate supply of hypochlorite solution in the reservoir. When necessary, make up some new solution. Test the chlorine residual frequently.

After the unit has been shut down, ensure the hypochlorite suction hose and strainer are removed from the solution reservoir. If necessary, clean the strainer. Also examine the balancing water valve strainer and clean it. It is very important that the hypochlorinator be kept clean because chlorine is highly corrosive and calcium granules can plug the feed lines.

REVERSE OSMOSIS WATER PURIFICATION UNIT (ROWPU)

Reverse osmosis is a process whereby the movement of a solvent flows through a semipermeable membrane into an area of lower solute concentration. In this process, the salts and minerals found in seawater remain on one side of the semipermeable membrane. The water passes through the member and is collected for use.

The ROWPU was designed as a lightweight unit capable of being air lifted to its deployment sight. It processes raw water, even seawater, into potable water. At present the ROWPU is a mobile water purifying unit that you can operate on a trailer, using a 30-generator power source, to supply drinking water for troops in the field. One unit and its relative location is shown in figure 6-20.

The water flow systems within the ROWPU process raw water to make it drinkable. Special high-pressure pumps, controlled by a built-in control panel, move the water through the ROWPU. As the raw water passes through the filter pipes, special selectively permeable membrane filters allow potable water through the filter. This potable water is gathered in a collection system and pumped to holding tanks. In the meantime, the impurities are maintained, for the most part, in solution and are discharged away from the raw-water inlet. This process allows for a much longer operating time between backwashes, as impurities are slowly collected on the filter media. In fact, if backwashing occurs in less than 4 hours of the previous backwash, it is necessary to manually rotate the reconditioning knob on the timer to the idle position.

The ROWPU is designed to produce as much as 10 gallons of drinking water a minute. This water is stored in collapsible tanks supplied with the trailer. These tanks can hold up to a total of 3,000 gallons.

When choosing the site to set up and operate the ROWPU (fig. 6-21), you should remember the following:

- When using a stream, river, or other flowing raw-water source, you should park the ROWPU trailer upstream from the campsite.

- Ensure the site provides wastewater drainage away from the raw-water inlet.

- Ensure the raw-water hoses supplied with the unit are approximately 75 feet long. Park the ROWPU trailer in position that enables the hoses to reach the water source, potable tanks, and wastewater discharge site.

- Ensure the ground at the chosen site is solid and fairly level. This will facilitate setup and support the additional weight of the water when the unit is in operation.

- Take advantage of available trees for both cover and concealment in a hostile environment.

- Take advantage of hard surfaces, such as finished roads, airfield aprons, and parking lots.

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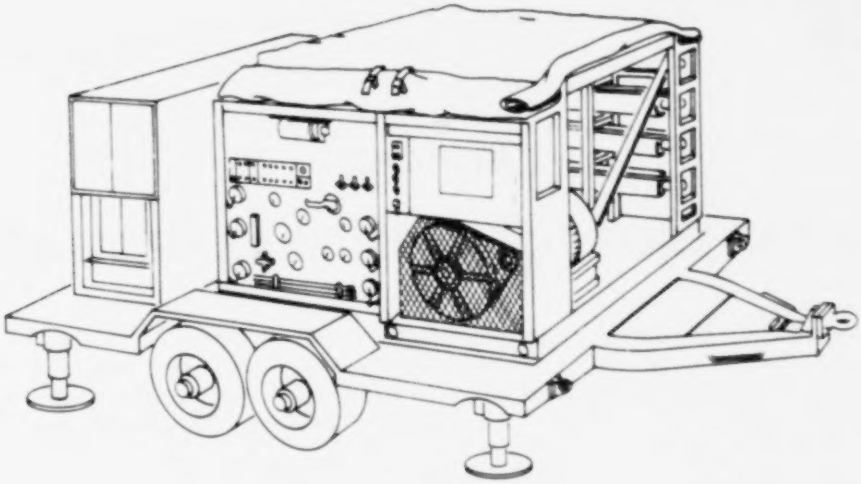

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Figure 6-20.—ROWPU 600 GPH, trailer mounted.

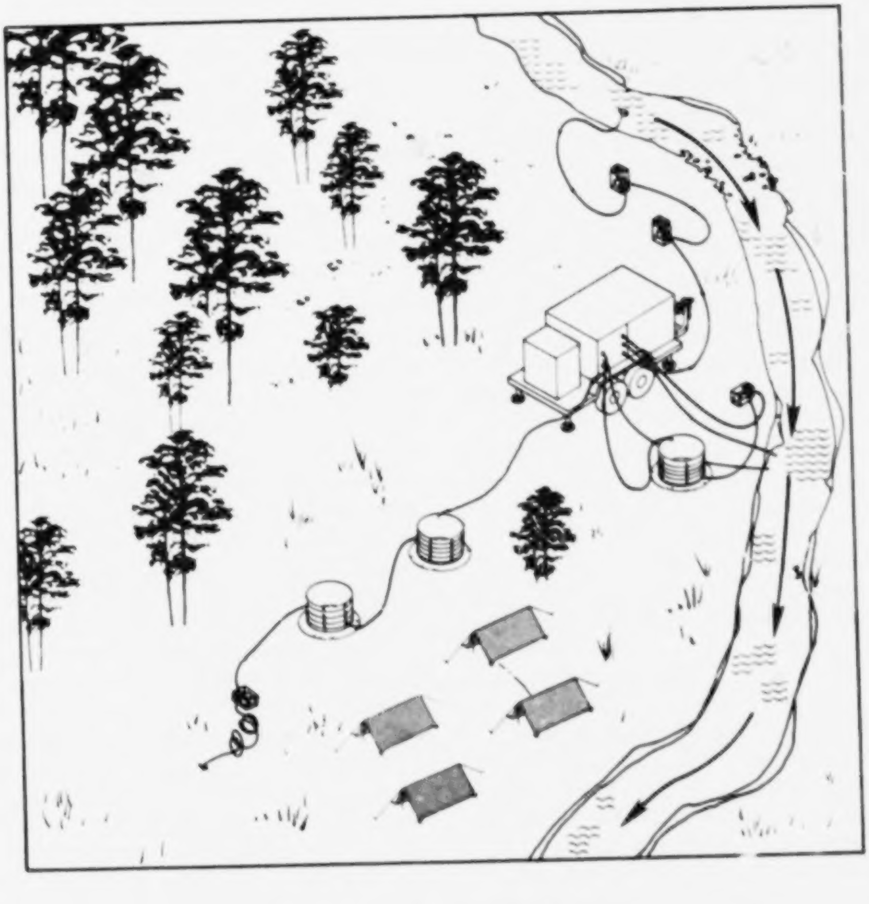

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Figure 6-21.—ROWPU location site.

CHAPTER 7

ADVANCED BASE FIELD SUPPORT FACILITIES

Learning Objective: Be able to explain the basic functions of the Advanced Base Functional Component System (NAVFAC P-437). You should also be able to identify, erect, construct, or repair the different types of advanced base field support facilities.

The Seabees are involved in many projects, ranging from building playgrounds in local communities to installing fountains and laying mosaic tile in an enlisted club. However, their primary responsibility must not be forgotten—the construction of advanced bases. It is the Seabee's job to get in the middle of a contingency situation and build the temporary facilities required to support U.S. military operations.

When these services are called upon, Seabees are expected to react expediently, and planning time is often limited. Planning is still required, however, to organize personnel working schedules, material requirements, and tool and equipment usage. At one time, this planning was not done in advance.

The need for advanced planning was discovered when our forces were jumping from island to island during World War II. It was realized that many of the requirements of the advanced bases were the same and a new advanced base could benefit from the planning done on a previous base. Advanced base requirements were grouped together into components according to their desired functions, and the ADVANCED BASE FUNCTIONAL COMPONENT (ABFC) SYSTEM was born. The ABFC System revolves around a building block type of system. The largest type of block is a COMPONENT, which brings together all of the people, facilities, equipment, and supplies required to perform a particular function. A component is made up of a FACILITY or a number of facilities that best meet your requirements. A facility is composed of smaller building blocks known as ASSEMBLIES. One or more assemblies are grouped together as required to make up the facility. A single assembly can often be used in several different facilities.

ABFC SYSTEM

To bring together all of the information of the ABFC System, the Naval Facilities Engineering Command published the *Facilities Planning Guide*, NAVFAC P-437, volumes 1 and 2.

Volume 1, which contains all of the reproducible drawings, is divided into three parts. Part 1 has all applicable plot plans for the components. Any facility drawing can be found in Part 2. All of the assembly drawings, which are used as the working drawings, make up Part 3. Each of the three parts is arranged in numerical/alphabetical sequence by their component, facility, or assembly number.

A picture may be worth a thousand words, but sometimes it takes a thousand and one words to convey an idea. To provide us with that "extra word," NAVFAC has published volume 2. Any written information concerning a component, facility, or assembly can be found by consulting this information-packed publication. Like volume 1, volume 2 is divided into three parts. Part 1 contains the component information. The facility information is in Part 2. Part 3 has all of the assembly information.

The advanced base support facilities discussed in this chapter will be the PORTABLE BATH UNIT, PORTABLE SPACE HEATER, CESSPOOLS, SEPTIC TANKS, TILE FIELDS, LATRINES, and GALLEY WASTE.

By the use of various components, facilities, and assemblies, a construction battalion is able to construct advanced bases. Advanced bases include administrative, medical, living, messing, and other essential facilities.

When the ABFC shipment arrives at the site, the assemblies and facilities should be distributed in the storage areas so they will be available in the order of erection or installation.

The first procedure is to check all parts against the bill of material. This helps to ensure that all the parts have been included in the assemblies. Visually inspect all the components for damage. Check for dents, cracks, broken parts, and loose or kinked connections. If an item is missing or damaged, you should report the discrepancy to your supervisor so steps can be taken to remedy the situation.

PORTABLE BATH UNIT

The nine-shower head portable bath unit is a liquid fuel-fired water-heating device that supplies warm water to each of the shower nozzles. The bath unit is equipped with the necessary water heater, water pump assembly, mixing unit, hoses, and shower stands to supply all the warm water needed for operation. The water pump draws water through the suction strainer and the hose from the water source and forces it through the discharge hose to the water heater. The water heater raises the temperature of the incoming water and maintains it at the desired temperature. The heated water is then forced through one discharge hose to the mixing unit where it is mixed with cold water to provide water at the desired temperature to the shower heads.

The electrical power required to operate the bath unit should be supplied by a self-contained portable 3 kW, 60-Hz, 208 V, three-phase power generator source. All electrically operated components of the bath unit should be grounded through a fifth wire incorporated in the power cables.

A description of major components to the portable bath unit is listed below. The location of each component can be seen in figure 7-1.

A. SHOWER STAND ASSEMBLY. Each of the three shower stand assemblies is equipped with three shower heads. Each shower head has a valve to control the water flow. A curtain is supplied to enclose each shower.

B. WATER HOSE ASSEMBLY. There are five 1-inch I. D. hoses, each measuring 7 1/2 feet in length. The hoses interconnect with the water pump assembly, the water heater assembly, the mixing valve assembly, and three shower stand assemblies.

C. MIXING VALVE ASSEMBLY. The mixing valve assembly mixes hot water from the water heater and cold water from the water pump and water source to provide heated water to the shower stands at temperatures of approximately 105 °F.

D. WATER HEATER. The water heater is a self-contained, liquified fuel-fired boiler that heats water supplied by the water pump. The major subassemblies or components that make up the water heater are the water vessel, burner assembly, blower assembly, control box assembly, sight glass assembly, and transformer and ignition cables.

E. DRUM FILL ADAPTER ASSEMBLY. The drum fill adapter assembly can be used with either a 55-gallon fuel drum or a 5-gallon gasoline can. The fuel level can be visually checked and refueled without disconnecting the fuel lines.

F. FUEL CONTAINER. The fuel container may be either a 55-gallon fuel drum or a 5-gallon gasoline can.

G. FUEL FEED AND RETURN HOSE ASSEMBLIES. Flexible hoses provide supply and return fuel between the fuel storage container and the fuel pump assembly on the water heater.

H. POWER CABLE ASSEMBLY. The power cable assembly consists of two cables that extend from the power source to the bath unit. The short cable connects to a 208 V, three-phase power source. The long cable connects to the short cable, the water heater, and the water pump.

I. WATER PUMP HEATER-HOSE ASSEMBLY. The assembly consists of one 1 1/2-inch I. D. hose measuring 6 feet in length that connects the water pump to the water heater.

J. WATER PUMP. The water pump draws water from the source through the intake hose and the in-line strainer then supplies it through a discharge line to the water heater.

K. SUCTION HOSE ASSEMBLY. This assembly has one 1-inch I. D. hose measuring 25 feet in length which connects the water supply to the water pump.

L. SUCTION STRAINER ASSEMBLY. The suction strainer assembly is connected to the suction hose assembly. It prevents leaves and debris from entering the water system.

Setting Up the Bath Unit

Locate the bath unit so drainage from the shower area is carried downstream or downhill from the suction hose strainer to prevent wastewater from being drawn back into the water source. If this arrangement is not possible, dig a ditch or build a dike around the shower stands to allow wastewater to drain away from the water source. When a pressurized water source is to be used, discharge the water into an open reservoir before it is drawn into the bath system. This prevents excessive strain on the water pump. Use the following procedures to set up the bath unit:

WARNING: Do not connect the water heater to an untested water supply. Contaminated water can cause illness or death.

CAUTION: To prevent equipment damage, be sure the hose couplings are free of dirt or foreign matter and the coupling gaskets are in place before you couple the hoses.

1. Connect the section hose strainer to the male end of a 25-foot-long, 1-inch I. D.

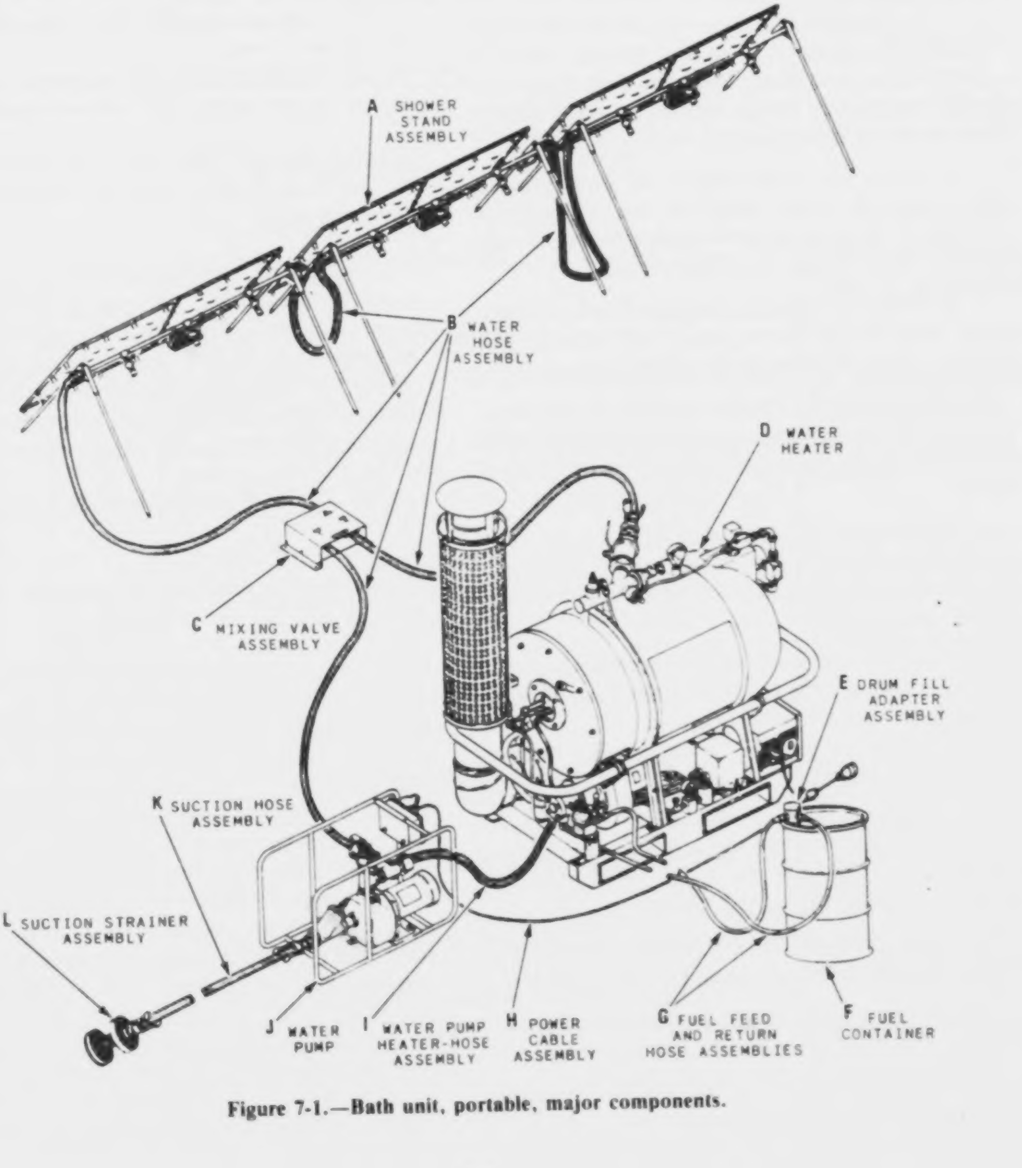

A SHOWER STAND ASSEMBLY
B WATER HOSE ASSEMBLY
D WATER HEATER
C MIXING VALVE ASSEMBLY
E DRUM FILL ADAPTER ASSEMBLY
K SUCTION HOSE ASSEMBLY
L SUCTION STRAINER ASSEMBLY
J WATER PUMP
I WATER PUMP HEATER-HOSE ASSEMBLY
H POWER CABLE ASSEMBLY
G FUEL FEED AND RETURN HOSE ASSEMBLIES
F FUEL CONTAINER

Figure 7-1.—Bath unit, portable, major components.

water hose and secure the cam lock locking levers.

2. Connect the female end of the water hose to the water pump suction port.

3. Place the water pump on a level surface approximately 20 feet from the water source. Be sure the suction line does not exceed 15 feet in length.

4. Place the suction hose assembly and strainer into the water source using one of two methods:

a. Place the strainer on a mound of stones or gravel and make a large pile of stones upstream from the strainer to divert debris from it.

b. Build a tripod using tree branches and suspend the strainer from the tripod. Build a barrier using tree branches upstream from the strainer to prevent leaves, weeds, or other debris from entering the strainer.

5. Place the water heater on level ground approximately 5 feet from the water pump. If possible, arrange a suitable shelter or windbreak for the water heater to conserve fuel.

6. Connect the male coupling of a 1 1/2-inch water hose to the water pump and connect the female end of the hose to the water heater intake.

7. Connect the female end of a 7 1/2 foot, 1-inch I. D. hose to the water heater and the male end of the hose to the HOT fitting on the mixing valve.

8. Connect the male end of a 7 1/2 foot, 1-inch I. D. hose to the water pump outlet and the female end of the hose to the COLD fitting of the mixing valve.

9. Erect the shower stand approximately 20 feet from the mixing valve. Connect sections of the shower stand assembly using a 7 1/2 foot, 1-inch I. D. hose. Install the cap on the shower stand end connector.

10. Connect the female end of a 25 foot, 1-inch I. D. hose to the MIXED fitting of the mixing valve. Connect the male end of the hose to the female fitting of the shower stand.

11. Install an elbow on the water heater with a slight turn to the right to seat the pin in the slot.

12. Insert a smokestack and guard assembly through the bracket onto the elbow.

13. Tighten the screw on the bracket to secure the smokestack and guard assembly.

14. Place the fuel container approximately 5 feet from the water heater.

WARNING: The fuel used with the bath unit is highly flammable and may be dangerous to human life if handled improperly. Tighten all fuel fittings firmly with a wrench to prevent leaks. Recheck all fittings when the water heater is operating to ensure there are no fuel leaks with the system under pressure.

15. Screw the drum fill adapter into the fuel container.

16. Connect the fuel line from the pump filter to suction the fitting on the drum fill adapter assembly.

17. Connect the fuel line from the pump to the return fitting.

18. Connect the cable assembly to the water heater, water pump, and power source.

WARNING: Use only the fuel specified. Failure to do so may result in injury to personnel or equipment.

CAUTION: The lack of lubrication may cause pump damage when straight gasoline is used as fuel. To avoid failure, when firing the fuel burner with gasoline, mix 1 quart of oil with each 5 gallons of gasoline. This mixture will provide internal lubrication for the fuel pump. To ensure a proper mixture, pour gasoline into the oil.

19. Fill the fuel container with approved fuel.

Operator's Preventive Maintenance Checks and Services (PMCS)

To ensure that the equipment is ready for operation at all times, it must be inspected systematically before operation, during operation, and after operation so defects may be discovered and corrected. The necessary preventive maintenance checks and services (PMCS) will be performed before operation. The defects discovered during operation of the unit will be noted, and the corrections made as soon as operation has ceased. Stop the operation immediately if a deficiency is noted which could damage the equipment. After operation, the necessary PMCS must be performed. Report defects or unsatisfactory operating characteristics beyond your scope to your supervisor.

The PMCS procedures are contained in table 7-1. They are arranged in logical sequence

Table 7-1.—Operator Preventive Maintenance Checks and Services

B-Before Operation D-During Operation A-After Operation

Item No.	INTERVAL			ITEM TO BE INSPECTED	Equipment Is Not Ready/Available If:
	B	D	A	PROCEDURE	
				BATH UNIT	
				MISCELLANEOUS ASSEMBLIES	
1				Power Cable Assembly	
	•			Check for broken insulation and loose or damaged connectors.	Defective power cable
				Suction Strainer Assembly	
	•	•		Check strainer at point of water intake. Clear any obstructions. Be sure that strainer is positioned away from debris and sediment.	Clogged or damaged strainer
				Water Hose Assembly	
	•	•	•	Check hoses and connections for cracks, leaks, or collapsed lines.	Leaky or damaged hoses or connections
				Smokestack and Guard Assembly	
	•	•	•	1. Check for tight connections, breaks, leaks, or foreign material lodged in pipes.	Defective or damaged exhaust system
		•		2. Check exhaust gases for light heat haze. If haze is present, depress spring-loaded rivet on blower shutter and adjust shutter up or down until exhaust gas is clear.	Maladjusted blower shutter
2				Shower Stand Assembly	
	•	•		1. Check for defective shower heads and couplings.	Damaged or clogged shower heads or leaky connections
	•			2. Check for clogged nozzles.	
3				Water Heater Assembly	
	•		•	1. Check fuel supply control assembly for leaks or incorrect fuel supply and return line connections.	Fuel supply and return lines reversed or damaged connections
	•	•		2. Check ignition cable for frayed insulation or damaged connections.	Defective ignition cable
	•		•	3. Check blower and water assembly for tight mounting.	Loose or broken mounting hardware
	•			4. Check fuel pump assembly for full prime.	
	•		•	5. Check air shutter assembly for binding, slippage, or damage.	Defective air shutter
	•			6. Check load limit switches to be sure they are not tripped from overload conditions.	

requiring a minimum amount of time and motion on the part of the personnel performing them and are arranged so there will be minimum interference between personnel performing checks simultaneously.

Preparation for Use

Before you start the bath unit, go to the "Operator's Preventive Maintenance Checks and Services (PMCS)" and do the "Before Operation" checks in table 7-1 and then proceed as follows:

- Make certain the water heater load limit switch is turned to OFF.

- Make sure the manual fuel valve is closed.

- Press the reset button to ensure the flame safeguard control is not locked out.

- Open the blower shutter approximately halfway.

- Open the fuel pump primer plug and fill the fuel container with fuel. Replace the plug.

- Make sure that one end of the hose is connected to the supply fitting of the fuel filter and to the fittings on the vent. Connect the return fuel line to the drum fill adapter.

NOTE: The operator must periodically monitor the level of the fuel supply. The fuel container should be kept as full as possible to reduce water condensation. The frequency of refueling depends on the size of the fuel container. Excessive water in the fuel supply decreases heater efficiency and corrodes both the chamber and the burner.

WARNING: Exposed fuel and fuel vapor can ignite or explode, resulting in possible serious injury and even death. Observe proper safety precautions when servicing the fuel system. Ensure the water heater is cold before servicing the burner.

- Check to see that all of the waterlines are connected.

- Be certain the water heater drain cock is closed.

- Check to be sure the smoke-pipe elbow, the two lengths of the smoke-pipe guard assembly, and the smoke pipe are securely installed.

Start-up Procedures

After having performed all the recommended PMCS and the water heater is ready for use, you should proceed as follows:

- Turn off the limit switch and connect the power cable to the power source.

- Close the fuel valve by turning it to the right.

- Remove the plug and fill the coupling with water.

- Replace the plug.

- Open the fuel valve and turn the load limit switch and power source ON. The fuel pressure gauge should indicate 100 psi.

- View the ignition spark through the sight tube after the power is turned ON.

- Wait 7 seconds; then view the combustion through the sight tube.

- If combustion does not occur after an additional 12-second wait, the buzzer sounds and the ignition spark shuts down. Wait 2 minutes after the buzzer sounds and press the safety reset button. If combustion still does not occur, troubleshoot the unit according to table 7-2.

- After start-up, the exhaust gases from the exhaust stack should be transparent and smokeless. If smoke is present, slowly open the air band on the blower assembly until the exhaust gases are transparent and smokeless. The water heater is now in automatic operation.

Shutdown Procedures

Perform the following shutdown procedures after normal use or when the equipment will not be used for an extended period:

- Turn off the fuel valve.

- Turn off the load limit switch.

- Turn off the water pump.

If there is danger of the bath unit freezing, perform the following procedures:

- Disconnect and drain all water hoses.
- Open the drain cock on the water pump by turning it to the left and tilt the water pump on end to let the water drain out.
- Reach under the water heater and open the drain cock by turning it to the left.

If the bath unit will not be used for 5 days or more, perform the following procedures:

- Remove the fuel feed hose from the fuel container.
- Place the end of the hose into a quart container.
- Fill the container with diesel fuel.
- Turn on the load limit switch and allow the unit to operate until the quart container is almost empty. Turn off the water heater fuel shutoff valve and let the system operate until the flame is extinguished.
- Turn off the load limit switch.

Troubleshooting Procedures

This section contains troubleshooting information for locating and correcting most of the operating troubles that may develop in your bath unit. The troubleshooting procedures are listed in table 7-2. The table lists the common malfunctions that you may find during operation or maintenance of the bath unit or its

Table 7-2.—Troubleshooting Procedures

MALFUNCTION
TEST OR INSPECTION
CORRECTIVE ACTION

1. WATER HEATER FAILS TO START

Step 1. Check source of electrical power supplied to water heater.

Check source of electrical power and connect to water heater.

Obtain power source and connect to water heater.

Step 2. Check load limit switch for amount of electrical power when switch is turned on.

Inspect master control box and notify direct support maintenance if faulty.

Inspect heater limit controls; adjust if necessary.

Step 3. Check flame safeguard control switch to see if it is tripped out.

Reset flame safeguard control. Call direct support maintenance if faulty.

Step 4. Check blower motor reset contactor to see if it is tripped.

Reset contactor.

If blower motor still does not run, replace blower motor.

Step 5. Check water supply in water heater tank.

Fill water heater tank with water.

Step 6. Check low water probe to see if it is defective.

Notify direct support maintenance.

Step 7. Check low water relay to see if it is defective.

Notify direct support maintenance.

Table 7-2.—Troubleshooting Procedures—Continued

MALFUNCTION
TEST OR INSPECTION
CORRECTIVE ACTION

---

2. FLAME FAILURE DURING FIRING CYCLE

Step 1. Check fuel supply in fuel container.
Fill container with fuel.

Step 2. Check fuel hoses for leaks.
Tighten couplings; replace fuel hose.

Step 3. Check fuel hose for clogs.
Disconnect fuel hose and clear all foreign matter and clogs from line.

Step 4. Check fuel nozzle for dirt and clogs.
Clean or replace nozzle.

Step 5. Check UV scanner tube to see if it is clogged.
Clear all obstructions from UV scanner tube.

Step 6. Check operation of flame safeguard control to see if it is defective.
Notify direct support maintenance.

Step 7. Check UV scanner to see if it is defective.
Notify direct support maintenance.

Step 8. Inspect fuel pump strainer to see if it is clogged.
Remove and clean strainer.

Step 9. Check fuel pump drive coupling for looseness.
Tighten pump drive coupling.

Step 10. Check fuel pump to see if it is defective.
Replace fuel pump.

Step 11. Check for presence of electric power at solenoid fuel valve.
Notify direct support maintenance.

Step 12. Check solenoid fuel valve to see if if is defective.
Replace solenoid fuel valve.

3. FUEL PRESSURE GAUGE INDICATES PRESSURE TOO LOW

Step 1. Check to see if burner control valve is defective.
Replace burner control valve.

Step 2. Check fuel pump pressure to see if it is 100 psi.
Adjust pump pressure.

Step 3. Check to see if fuel filter is dirty or clogged.
Clean filter.

Step 4. Check for breaks in fuel hoses or loose couplings.
Tighten couplings or replace hose.

MALFUNCTION
TEST OR INSPECTION
CORRECTIVE ACTION

---

4. FUEL PRESSURE GAUGE INDICATED PRESSURE TOO HIGH

Step 1. Check to see if fuel pressure gauge is defective.
Replace fuel pressure gauge.

Step 2. Check to see if fuel pump pressure is properly adjusted.
Adjust fuel pump pressure.

Step 3. Check to see if fuel nozzle is defective.
Clean fuel nozzle.
Replace fuel nozzle.

Step 4. Check to see if return fuel hose is restricted.
Disconnect return fuel hose and remove restriction.

5. NOISY FUEL PUMP

Step 1. Check suction hose for leaks.
Tighten suction line connections.
Replace suction hose if cracked.

Step 2. Inspect to see if fuel pump strainer is clogged.
Clean fuel pump strainer.

Step 3. Check fuel filter to see if it is clogged or dirty.
Remove and replace fuel filter.

Step 4. Check to see if fuel pump is overheating or noisy.
Replace fuel pump.

Step 5. Check to see if fuel pump is primed.
Prime fuel pump.

6. PRESSURE GAUGE INDICATES PULSATING PRESSURE

Step 1. Inspect suction hose for leaks.
Tighten suction hose connections.

Step 2. Check to see if fuel pump strainer is clogged.
Remove and replace strainer.

Step 3. Check to see if fuel filter is clogged.
Remove and replace filter.
If fuel filter is not clogged, go to Step 4.

Step 4. Check to see if burner nozzle is defective.
Replace burner nozzle.

Step 5. Check to see if fuel pressure gauge is defective.
Replace fuel pressure gauge.

Table 7-2.—Troubleshooting Procedures—Continued

MALFUNCTION
TEST OR INSPECTION
CORRECTIVE ACTION

7. FUEL PUMP LEAKS

Step 1. Check to see if strainer cover is loose.
Tighten all cover screws.

Step 2. Check to see if plugs are loose.
Tighten plugs.

Step 3. Check shaft seals for leaks.
Replace fuel pump.

Step 4. Check fuel pump for cracks.
Replace fuel pump.

8. FUEL PUMP FAILS TO DELIVER FUEL TO BURNER

Step 1. Check fuel supply in fuel container.
Fill fuel container.

Step 2. Check suction hose for any leaks.
Tighten suction hose connections.

Step 3. Check to see if pump rotation is reversed.
Interchange any two of the three 208 volt, three-phase electrical supply lines at the power source.

Step 4. Check to see if supply and return fuel hoses are reversed.
Disconnect fuel lines and reconnect in proper place.

Step 5. Check fuel pump strainer for dirt or clogs.
Remove strainer and replace.

Step 6. Check for clogged fuel nozzle.
Remove nozzle and clean.

Step 7. Check fuel pump drive coupling for looseness.
Tighten fuel pump drive coupling.

Step 8. Check to see if solenoid valve activates.
Notify direct support maintenance.

Step 9. Check fuel hoses for restrictions.
Disconnect fuel hose and remove restriction.

9. BURNER FAILS TO IGNITE OR IS DELAYED

Step 1. Check amount of fuel in fuel container.
Fill container with fuel.

Table 7-2.—Troubleshooting Procedures—Continued

MALFUNCTION
TEST OR INSPECTION
CORRECTIVE ACTION

---

9. BURNER FAILS TO IGNITE OR IS DELAYED (CONT'D)

Step 2. Check to see if fuel hoses are clogged.

Clean fuel hoses.

Clean fuel filter.

Step 3. Check to see if fuel nozzle is clogged.

Clean or replace fuel nozzle.

Step 4. Check for water in fuel.

Drain fuel supply and refill with proper fuel.

Step 5. Check electrodes for carbon deposits.

Clean electrodes.

Step 6. Check electrodes for proper adjustment.

Adjust electrodes.

Step 7. Check ignition transformer for signs of damage.

Remove ignition transformer.

Step 8. Check to see if cable assembly connection from transformer to burner is disconnected.

Connect cable assembly.

Step 9. Check electrode porcelain for breaks or cracks.

Replace electrode.

10. BLOWER MOTOR CONTACTOR CONTINUES TO TRIP

Step 1. Check fuel pump and motor for obstructions or binding.

Loosen setscrew at fuel pump shaft and check blower rotation.

Replace fuel pump or motor.

11. EXHAUST GASES FROM SMOKESTACK ARE SMOKY

Step 1. Check burner electrode spark.

Adjust electrodes.

Replace electrodes.

Step 2. Check for contaminated fuel.

Replace fuel if contaminated.

Step 3. Check to see if nozzles and screen are clogged.

Clean or replace clogged nozzles.

Step 4. Check blower operation for obstruction.

Loosen setscrew at fuel pump shaft and check blower rotation.

MALFUNCTION
TEST OR INSPECTION
CORRECTIVE ACTION

---

11. EXHAUST GASES FROM SMOKESTACK ARE SMOKY (CONT'D)

Step 5. Check for low output voltage from power source.
Adjust power source output voltage.

12. SMOKE ESCAPING FROM AROUND SMOKEBOX COVER

Step 1. Check boiler box gasket for excessive wear and deterioration.
Replace gasket.

Step 2. Check to see if nuts securing smokebox cover and burner head assembly are torqued properly.
Torque nuts.

13. WATER TEMPERATURE GAUGE SHOWS WATER OVERHEATS

Step 1. Check 0-250°F temperature control setting to see if it is too high.
Adjust 0-250°F temperature control.

Step 2. Check 0-250°F temperature control to see it if is defective.
Replace 0-250°F temperature control.

Step 3. Check for defective low water probe.
Notify direct support maintenance.

14. BLOWER AND FUEL PUMP MOTOR NOISY

Step 1. Check blower obstruction.
Feel blower motor to see if it overheats.
Loosen setscrew at fuel pump shaft and check blower rotation.
Replace blower motor.

15. WATER PUMP FAILS TO DELIVER WATER

Step 1. Check to see if water pump motor runs.
Replace water pump motor.
Notify direct support maintenance.

Step 2. Check water pump for reversed rotation.
Interchange any two of the external leads at the motor.

Step 3. Check water pump shaft seals for leaks.

16. WATER PUMP FAILS TO ROTATE

Step 1. Check to see if electric motor is operating.
Tighten electrical connections.
Replace motor.

Table 7-2.—Troubleshooting Procedures—Continued

MALFUNCTION
  TEST OR INSPECTION
    CORRECTIVE ACTION

---

17. WATER PUMP ASSEMBLY NOISY

Step 1. Check water pump assembly for proper operation.

Replace water pump motor.

18. SHOWER STAND NOZZLES NOT DISCHARGING ENOUGH WATER

Step 1. Check water flow control valves at shower nozzles to see if they are closed or damaged.

Replace water flow control valve.

Step 2. Check for closed or pinched fittings.

Replace fittings.

---

components. You should perform the tests/inspections and corrective actions in the order listed. Each malfunction for an individual component, unit, or system is followed by a list of tests or inspections to help you determine what corrective action(s) to take.

This manual does not attempt to list all possible malfunctions and corrective actions or all the necessary tests and inspections. Remember, you should always notify your supervisor when something unusual occurs.

PORTABLE SPACE HEATER

Types I and II portable space heaters are designed to heat tents. The heater assembly consists of essentially a heater body (top and bottom), adapter ring, grate or liquid fuel burner assembly, and air conditioning-heating pipe sections. (See figs. 7-2 and 7-3.)

Type I heaters may be operated with wood or coal. Type II heaters operate with diesel oil, light fuel oil, or gasoline. The heat output is measured in British thermal units (Btu). The fuel consumption rates are as follows:

Type I (coal)	1/4 ton per week
Heat output (normal)	35,000 Btu per hour
(maximum)	45,000 Btu per hour
Type II (gasoline or oil)	5 gallons for 10 to 30 hours

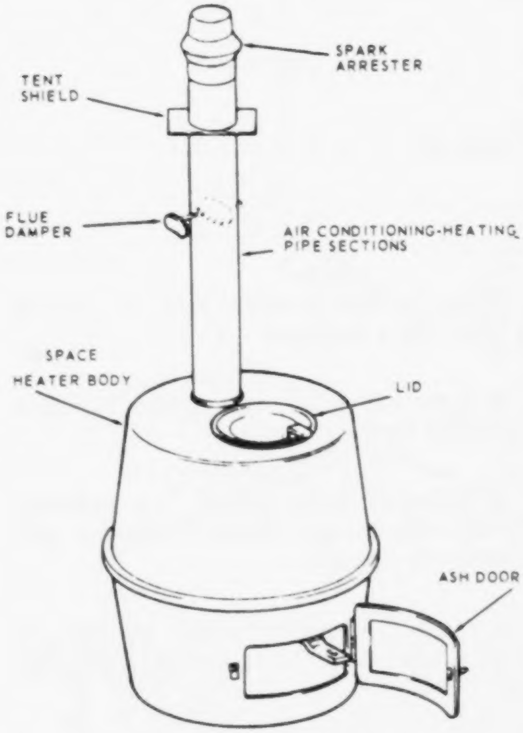


Figure 7-2.—Space heater (Type I).

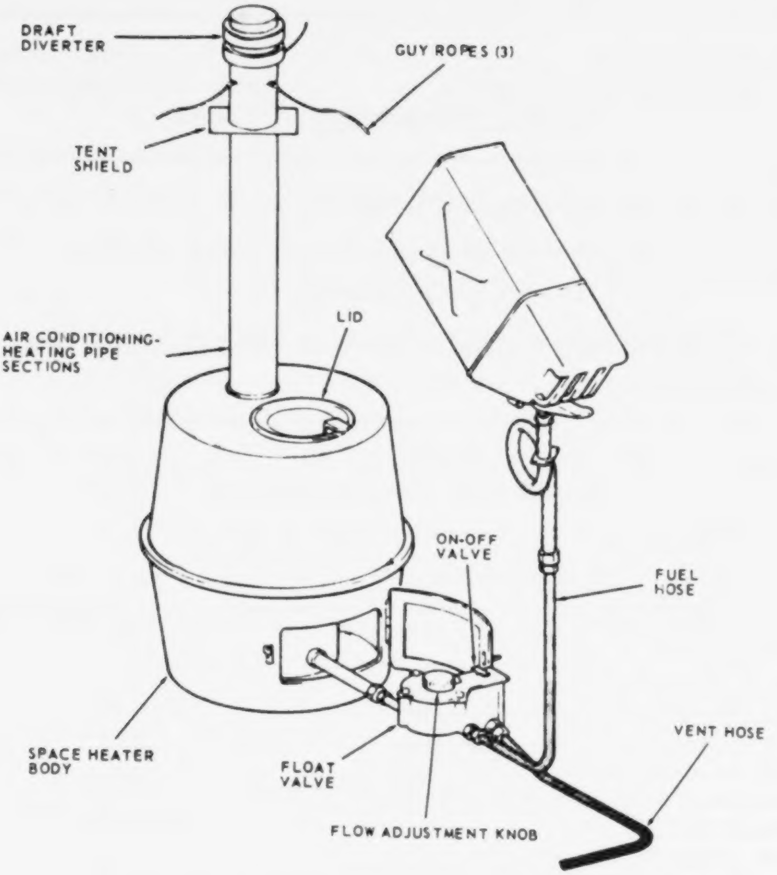

DRAFT DIVERTER
GUY ROPES (3)
TENT SHIELD
LID
AIR CONDITIONING-HEATING PIPE SECTIONS
ON-OFF VALVE
FUEL HOSE
VENT HOSE
SPACE HEATER BODY
FLOAT VALVE
FLOW ADJUSTMENT KNOB

Figure 7-3.—Space heater (Type II).

Before you place the heater in service, perform the following procedures:

- Inspect the entire heater assembly for signs of physical damage.

- Inspect the heater to be sure it is assembled properly, secure, clean, correctly adjusted, and mechanically operable.

- Correct deficiencies within the scope of organizational maintenance before placing the heater in service.

- Perform the daily preventive maintenance services.

Setting Up the Heater

Place the heater base on the ground or floor of the tent. In tents with wooden floors, the base should be set in a sandbox or on sheeting that is designed to protect the floor from heat. In an emergency, a pile of stones or brickbats may be used. The sandbox must meet the following standards:

1. It must be no smaller than 40 inches long by 28 inches wide by 4 inches high. Use 2- by 4-inch lumber for the framework.

2. It must have a sheet metal bottom to act as an insulating shield.

3. The stove should be placed in the center of the box with a minimum of 3 1/2 inches of sand

between the bottom of the stove and the metal insulation shield.

4. Areas surrounding the stove should be void of combustibles at any point closer than 4 feet on a horizontal plane from the floor to the ceiling of the tent or building. Necessary material may be secured locally upon approval of the local commander.

To assemble and set up the Type I space heater components, refer to figure 7-4 and proceed as follows:

1. Assemble the grate.

2. Place the adapter ring on top of the base. Level the heater base by sight.

3. Insert the grate assembly in the adapter ring with the shaker catch facing the ash door and the draw grate on the bottom.

4. Place the top of the space heater on the adapter ring.

5. Assemble the air-conditioning smoke pipe as follows:

a. Join the formed edges of a curved sheet of metal to form a cylindrical pipe.

CAUTION: Hold the sheet metal securely while curling it to prevent it from slipping and causing severe cuts.

b. From the inside, insert a split rivet through each of the three holes in the smoke-pipe sections. Spread the tines of the rivet, and hammer them flat.

NOTE: The damper is not required in the smoke pipe when burning liquid fuel.

c. In one section of the smoke pipe, insert the damper. Punch a hole through the pipe at a position half the length of the pipe. Hold the damper in place inside the pipe, and thread the damper shaft through the holes locking the curved shank of the damper shaft into the center slot of the damper. When properly locked together, the damper and operating handle are parallel.

6. Assemble the smoke-pipe sections starting with the section of pipe having the damper installed. Place the smooth female end of the pipe over the steel collar on the heater top.

NOTE: When conditions permit, use six lengths of pipe extended straight up. Elbows and horizontal pipes reduce the draft and cut down the heat output.

7. Install the spark arrester on one pipe section above the heater or on top of the smoke pipe outside of the shelter.

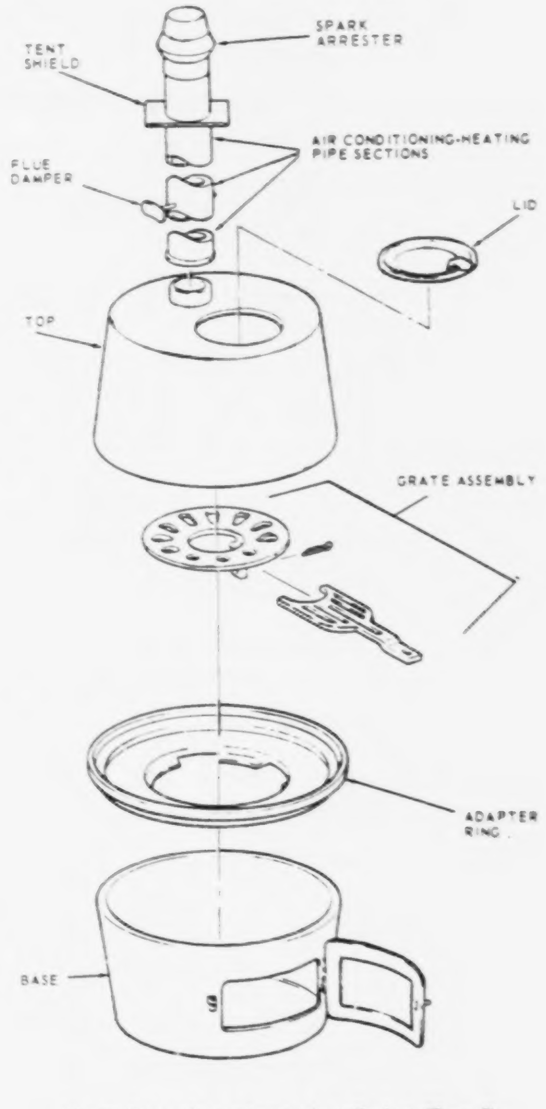


Figure 7-4.—Space heater installation (Type I).

To assemble and set up the Type II space heater, refer to figure 7-5 and proceed as follows:

1. Place the adapter ring on the heater base.

2. Set the oil-pot burner in the adapter ring so the fuel inlet pipe faces the ash door opening.

3. Turn the adapter ring to the right until it engages the locking clips on the right side of the door opening.

4. Install the flame spreader in the center of the burner.

5. Attach the float valve nipple to the smaller end of the pipe reducer located on the oil-pot burner. Make sure the connection is tight enough to hold the valve in a level position and to prevent leaks.

6. Place the top of the space heater on the adapter ring.

7. Assemble the smoke pipe.

8. Install the draft diverter on top of the stack and anchor it with guy ropes.

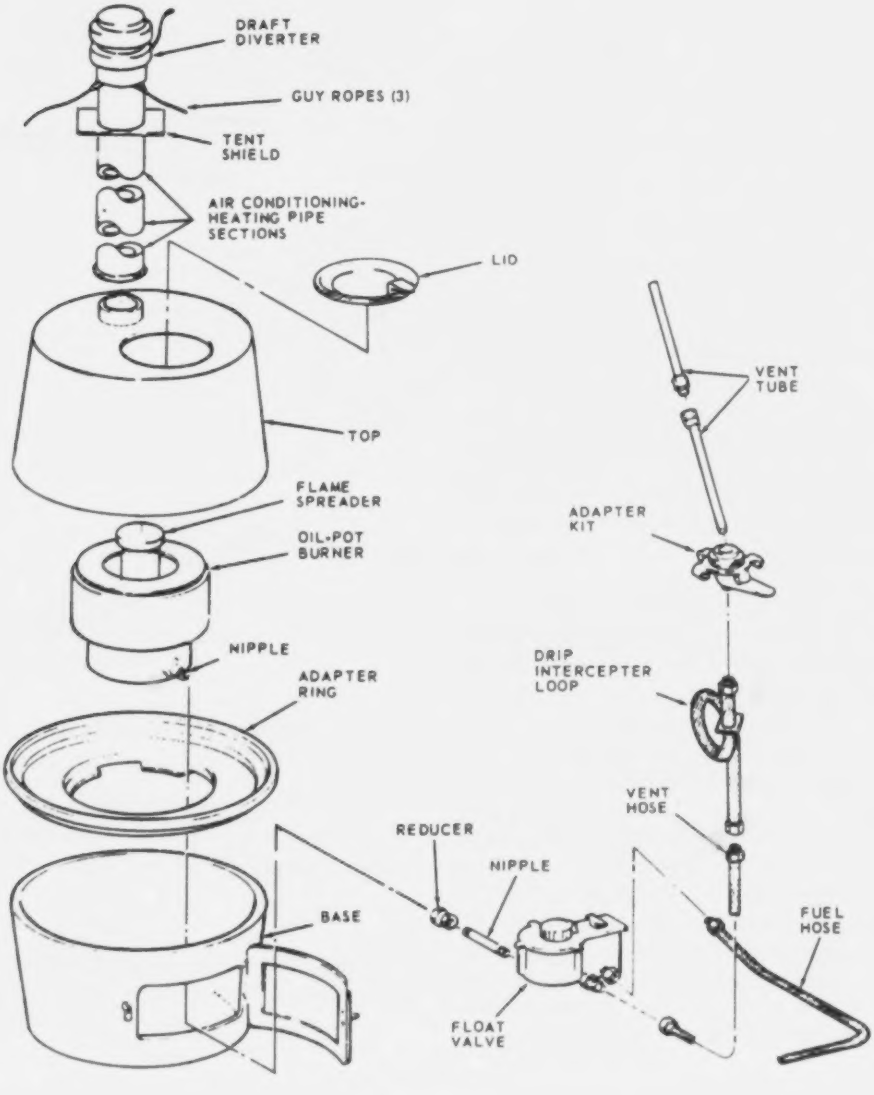

DRAFT DIVERTER
GUY ROPES (3)
TENT SHIELD
AIR CONDITIONING-HEATING PIPE SECTIONS
LID
VENT TUBE
TOP
FLAME SPREADER
OIL-POT BURNER
ADAPTER KIT
NIPPLE
ADAPTER RING
DRIP INTERCEPTER LOOP
VENT HOSE
REDUCER
NIPPLE
BASE
FUEL HOSE
FLOAT VALVE

Figure 7-5.—Space heater installation (Type II).

CAUTION: Install the guy line radially to eliminate contact with the smoke pipe. Lines should be erected and anchored so the movement of the tent does not adversely affect the stability of the smoke pipe.

Refer to figure 7-6 and assemble the fuel can adapter, and insert it in the fuel can as follows:

CAUTION: When changing fuel cans, release the cam before removing the adapter from the empty can. The washer on the adapter may squeeze out of place when the adapter is screwed into place on the fuel can. Wipe excess fuel from the washer, washer seat, and the lid of the fuel can.

1. Attach the male end of one fuel hose to the drip loop hose of the adapter, and attach the opposite female end of the hose to the male fuel inlet fitting of the float valve.

2. Attach the other length of hose to the overflow fitting (under the center of the float valve) to carry off any possible overflow. This hose must drain downward and discharge into a safe outside location.

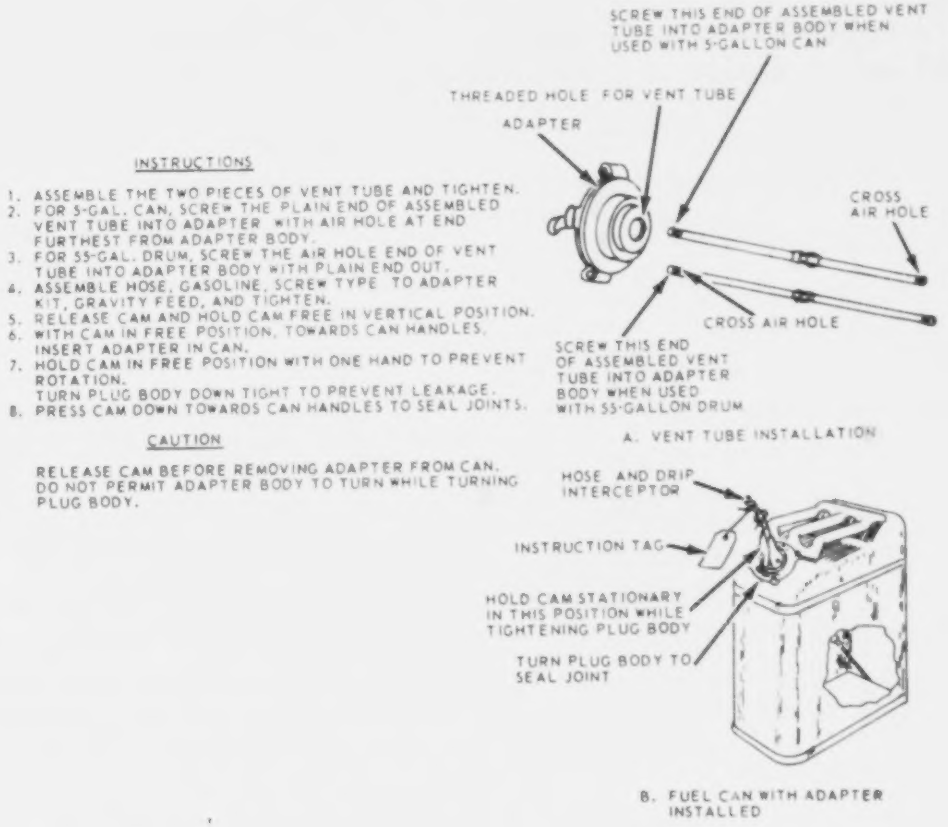
CAUTION: Be sure the fuel from the fuel can is connected to the male fitting marked INLET on the valve.

3. Make sure the inlet shutoff knob on the float valve is in the OFF position.

4. Invert the fuel can on a support no less than 1 foot or more than 8 feet above the float valve.

Preventive Maintenance

To ensure the space heater is ready for operation at all times, it must be inspected


SCREW THIS END OF ASSEMBLED VENT TUBE INTO ADAPTER BODY WHEN USED WITH 5-GALLON CAN
THREADED HOLE FOR VENT TUBE
ADAPTER
CROSS AIR HOLE
CROSS AIR HOLE
SCREW THIS END OF ASSEMBLED VENT TUBE INTO ADAPTER BODY WHEN USED WITH 55-GALLON DRUM
HOSE AND DRIP INTERCEPTOR
INSTRUCTION TAG
HOLD CAM STATIONARY IN THIS POSITION WHILE TIGHTENING PLUG BODY
TURN PLUG BODY TO SEAL JOINT

INSTRUCTIONS

1. ASSEMBLE THE TWO PIECES OF VENT TUBE AND TIGHTEN.
2. FOR 5-GAL. CAN, SCREW THE PLAIN END OF ASSEMBLED VENT TUBE INTO ADAPTER WITH AIR HOLE AT END FURTHEST FROM ADAPTER BODY.
3. FOR 55-GAL. DRUM, SCREW THE AIR HOLE END OF VENT TUBE INTO ADAPTER BODY WITH PLAIN END OUT.
4. ASSEMBLE HOSE, GASOLINE, SCREW TYPE TO ADAPTER KIT, GRAVITY FEED, AND TIGHTEN.
5. RELEASE CAM AND HOLD CAM FREE IN VERTICAL POSITION.
6. WITH CAM IN FREE POSITION, TOWARDS CAN HANDLES, INSERT ADAPTER IN CAN.
7. HOLD CAM IN FREE POSITION WITH ONE HAND TO PREVENT ROTATION.
   TURN PLUG BODY DOWN TIGHT TO PREVENT LEAKAGE.
8. PRESS CAM DOWN TOWARDS CAN HANDLES TO SEAL JOINTS.

CAUTION

RELEASE CAM BEFORE REMOVING ADAPTER FROM CAN. DO NOT PERMIT ADAPTER BODY TO TURN WHILE TURNING PLUG BODY.

A. VENT TUBE INSTALLATION

B. FUEL CAN WITH ADAPTER INSTALLED

Figure 7-6.—Fuel can adapter installation.

systematically so the defects may be discovered and corrected before they result in serious damage or failure. The preventive maintenance checks and services to be performed are listed and described in table 7-3. The item numbers indicate the sequence of inspections. Defects discovered during operation of the unit should be noted for correction in the near future, preferably as soon as operation has ceased. If a deficiency is found during operation that could damage the equipment, stop the unit. All shortcomings should be recorded together with corrective action taken at the earliest opportunity.

Troubleshooting Procedures

Table 7-4 provides information useful in diagnosing and correcting unsatisfactory operation or failure of the space heater. Each malfunction stated is followed by a list of probable causes of trouble. The corrective action recommended is described opposite the probable cause.

Table 7-3.—Preventive Maintenance Checks and Services

Item Number	Interval						B - Before operation D - During operation	A - After operation W - Weekly M - Monthly Q - Quarterly
	Operator					Org.		
	Daily							
	B	D	A	W	M	Q	Item to be Inspected	Procedure
							M1941 TYPE I	
1	X						Space heater	Inspect for proper installation.
2	X		X				Grate	Inspect for level condition and that draw grate operates smoothly.
				X				Inspect for cracked or warped condition and replace as required.
3	X						Air conditioning-heating pipe (smoke pipe)	Inspect pipe sections for security.
		X	X					Inspect pipe joints for loose fit and leaks.
				X				Remove pipe sections for cleaning. Replace as required. Make sure pipe sections fit tight.
4	X						Tent shields	Inspect for proper installation.
5	X		X				Damper	Inspect for proper operation.
6	X						Shovel, shaker, and poker	Make sure accessories are available.
		X					(Shaker and poker)	Use sparingly.
			X				Accessories and heater lid	Make sure accessories and heater lid are available.
7		X					Ashes and clinkers	Remove every 3 to 4 hours.
			X	X				Remove all ashes and clinkers.
8				X			Spark arrester	Inspect for accumulation of soot - clear.
9				X			Space heater assembly	Apply medium oil to all parts showing signs of rust.

Table 7-3.—Preventive Maintenance Checks and Services—Continued

Item Number	Interval						B - Before operation D - During operation	A - After operation W - Weekly M - Monthly Q - Quarterly
	Operator				Org.			
	Daily							
	B	D	A	W	M	Q	Item to be Inspected	Procedure
							M1941 TYPE II	
1	X						Oil burner	Inspect for proper installation.
					X			Inspect for dirt on burner bottom.
		X						Listen for noisy burner operation.
				X				Clean soot and carbon from small hole in burner pot.
				X				Clean dirt from bottom of burner.
2	X	X	X				Air conditioning-heating pipe	Inspect pipe sections for security and evidence of leaks.
				X				Remove pipe sections for cleaning. Replace as required. Make sure pipe sections fit tight.
3	X		X				Damper	Inspect damper for proper operation.
4	X						Float valve	Inspect for level position.
	X	X						Inspect for leaks.
			X	X				Inspect for secure mounting and that controls are undamaged.
				X				Inspect control for proper operation.
				X				Remove strainer; clean and replace.
5	X						Tent shields	Inspect for proper installation.
6	X						Guy lines	Adjust guy lines attached to draft diverter.
7	X						Adapter kit	Inspect for proper assembly and leaks.
8	X	X					Fuel hoses	Inspect hoses for proper routing.
		X						Inspect overflow hose for evidence of fuel overflow.
9	X	X	X	X			Fuel can and hose	Inspect for leaks.

CESSPOOLS, SEPTIC TANKS, TILE FIELDS, AND LATRINES

Various facilities are used for the treatment and disposal of sewage at installations where common sewers are not available. These facilities include cesspools, septic tanks, tile fields, and field-type latrines. Information on each of these facilities is provided below.

CESSPOOLS

Leaching cesspools are usually dry-laid masonry or brick-lined wells without any masonry

Table 7-4.—Troubleshooting

Malfunction	Probable cause	Corrective action
	Type I	
1. Draw grate locked	Clinkers lodged in grate openings.	Remove clinkers as soon as possible.
2. Stove does not heat properly	a. Ash door is closed.	a. Open ash door.
	b. Damper blocked or closed.	b. Remove pipe and clean damper; open damper.
3. Excessive smoke of dark color	a. Too much fuel added at one time.	a. Reduce quantity of fuel added but add fuel more often.
	b. Accumulation of soot in stack.	b. Remove and clean stack.
	c. Accumulation of ashes.	c. Shake down fire and clean out ashpit.
	Type II	
1. Burner does not fire	a. Fuel line to burner clogged.	a. Clean out fuel line with compressed air.
	b. Fuel tank empty.	b. Fill fuel tank.
	c. Float valve inlet knob turned to OFF position.	c. Set knob to ON position.
	d. Float valve adjustment knob improperly set.	d. Reset adjustment knob to correct number.
2. Incomplete combustion	a. Excess carbon in burner.	a. Burn out carbon and do not operate at such a high rate.
	b. Dirt in fuel.	b. Clean strainer in float valve with an approved cleaning solvent or compressed air.
3. Stove does not heat properly	a. Dirt in fuel.	a. Clean strainer in float valve with an approved cleaning solvent or compressed air.
	b. Accumulation of soot in stack.	b. Clean stack.
	c. Damper stuck.	c. Clean stack.
	d. Fuel too heavy.	d. Remove pilot ring from burner.
4. Any flow of fuel from overflow hose	a. Valve too far out of level to operate properly.	a. Adjust valve level by eye; a level is not necessary.
	b. Dirt under inlet float needle seat.	b. Remove valve. Take outside tent, clean strainer, and flush out valve. Do not disassemble valve.
	c. Float valve sticks at times.	c. Remove valve and take outside tent. Remove valve cover and check movement of float pivot mechanism. Replace valve if defective.
	d. Defective float in valve.	d. Remove cover and check float. If float has any liquid in it, replace valve.

at the bottom; the sewage flows into them and leaches out into the soil. Floating solids collect at the top and settling solids collect at the bottom of the well. The leaching capacity of the well is exhausted when the solids accumulate and clog the soil. (See fig. 7-7.) The use of chemicals is not recommended for increasing the useful life of a cesspool.

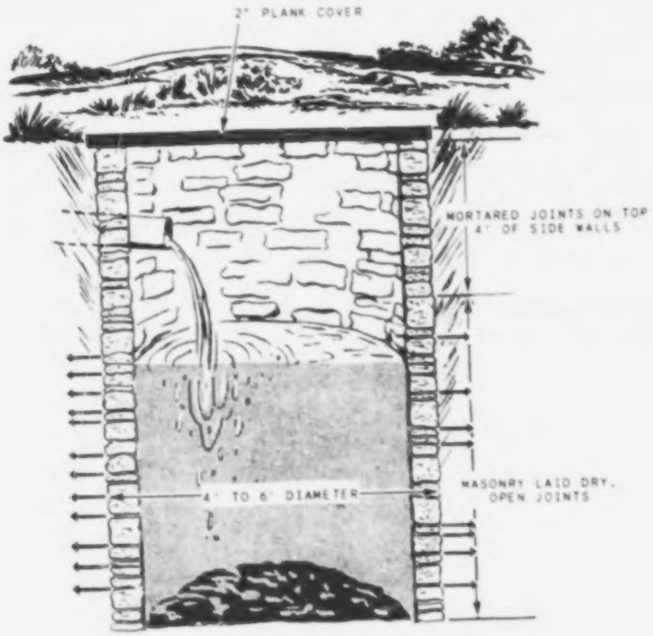
When the first cesspool becomes filled, a second well may be constructed to take the overflow from the first. In such cases, the first cesspool should operate as a septic tank to collect the settling and floating solids and provide a trapped outlet on the connection leading to the next leaching cesspool. Septic tanks can be placed advantageously ahead of leaching cesspools in larger installations. Leaching cesspools should not be placed closer together than 20 feet by out-to-out measurement of the walls.

Leaching cesspools should be used only where the subsoil is porous to a depth of at least 8 or 10 feet and where the groundwater is normally below this elevation. When cesspools are located in fine sand, the leaching area can be increased by surrounding the walls with graded gravel.

The number and the size of cesspools required depend on the quantity of sewage and the leaching characteristics of the total exterior percolating area above the groundwater table, including bottoms and sidewalls below the maximum-flow lines. The allowable rate of sewage application per square foot per day, based on the recommended leaching test, is provided below. Soils that require more than 30 minutes for a fall of 1 inch are unsatisfactory for leaching, and some other disposal method must be used.

Time for water to fall 1 inch (minutes)	Allowable rate of sewage applicable (gallons per square foot of percolating area per day)
1	5.3
2	4.3
5	3.2
10	2.3
30	1.1

The test for leaching should be made by digging a pit about one-half the proposed depth of the cesspool, making a test hole 1 foot square and 18 inches deep at the bottom. The test hole is filled with 6 inches of water that is allowed to drain off. Six inches of water is again added, and


2" PLANK COVER
MORTARED JOINTS ON TOP 4' OF SIDE WALLS
4' TO 6' DIAMETER
MASONRY LAID DRY, OPEN JOINTS

54.272

Figure 7-7.—Leaching cesspool.

the downward rate of percolation is measured in minutes required for the water surface to lower 1 inch in the hole.

SEPTIC TANKS

For emergency and temporary construction, septic tanks are made of wood or nonreinforced concrete with wood covers and baffles. Reinforced concrete construction is more suitable for permanent installations. (See fig. 7-8.) The tank capacity should equal a full day's flow, plus an allowance of from 15 to 25 percent for sludge capacity. The minimum desirable size of a tank is 1,000 gallons.

In constructing a septic tank, see that the length of the septic tank is not less than two or more than three times the width. The liquid depth should not be less than 4 feet for the smaller tanks and 6 feet for the larger ones. Manholes should be provided over the inlet and outlet pipes and over the low points in the bottom of hopper bottom tanks. The roof of the tank may be covered with earth, but access openings should extend at least to the ground surface. Although ells or tees can be used at inlet and outlet connections, straight connections are better for rodding (cleaning out). Instead of ells, wooden baffles, located approximately 18 inches from the ends of the tank and extending 18 inches below and 12 inches above the flow line, are provided. Elevations should permit free flow into and out of the tank. The bottom of the inlet sewer should be at least 3 inches above the water level in the tank. The inlet and outlet connections should be sufficiently buried or otherwise protected to prevent damage by traffic or frost.

Although properly designed septic tanks require little operating attention, they must be inspected periodically; the frequency is determined by the size of the tank and the population load. The minimum frequency should be once every 2 months at periods of high flow. The inspection should be made to assure that the inlet and outlet are free from clogging, the depth of scum and sludge accumulation is not excessive, and the effluent passing to subsurface disposal is relatively free from suspended solids. A high concentration of suspended solids in the effluent quickly clogs

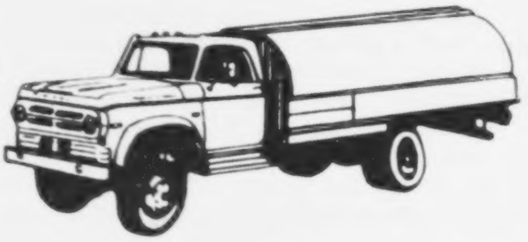


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Figure 7-9.—Tank and diaphragm-pump assembly for cleaning septic tanks.

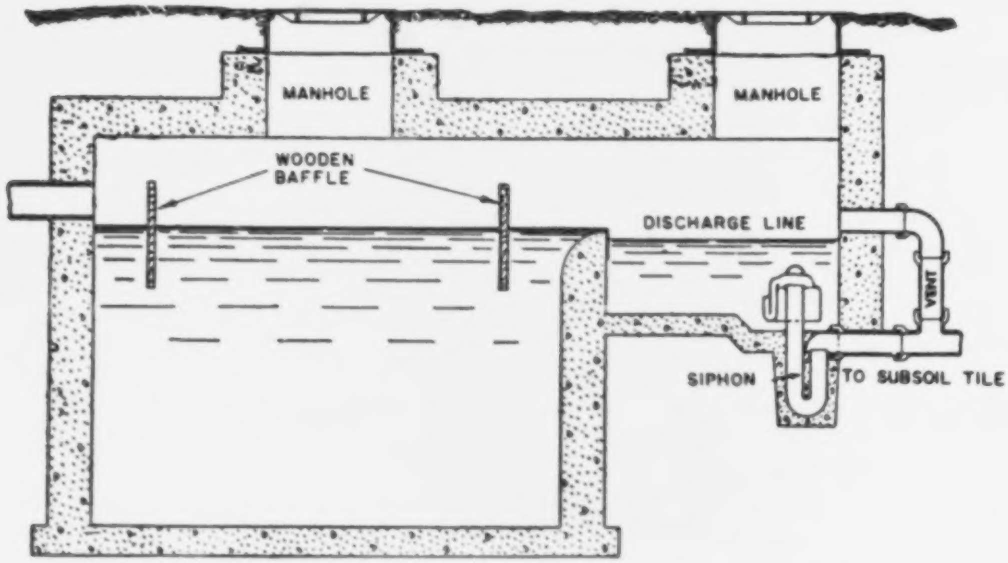

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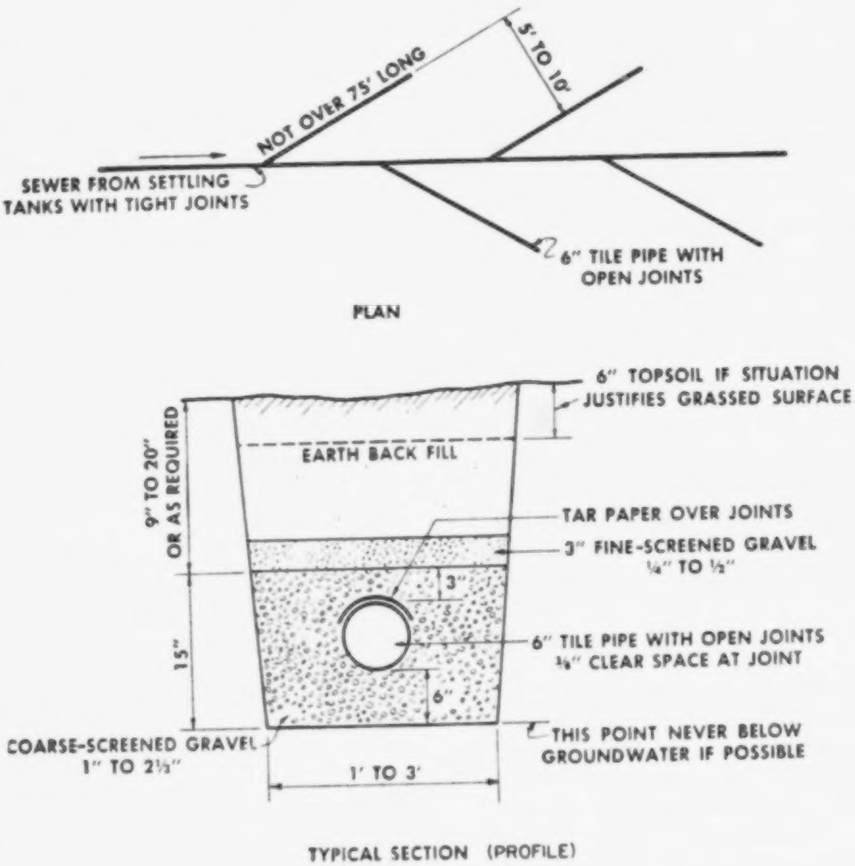
Figure 7-8.—Septic tank.

subsurface disposal facilities. Sludge and scum accumulation should not exceed one fourth of the tank capacity. It should not be assumed septic tanks liquefy all solids, they never need cleaning, and the effluent is pure and free from germs. Perhaps 40 to 60 percent of the suspended solids is retained, and the rest is discharged in the effluent.

Separating sludge and scum from the liquid in septic tanks is difficult. In small tanks, these wastes are customarily mixed; the entire contents are removed when the tanks are cleaned. The material removed contains fresh or partially digested sewage solids that must be disposed of without endangering the health of personnel. Disposal through manholes in the nearest sewer system, as approved by local authorities, or burial in shallow furrows on open land is recommended. A diaphragm sludge pump is best suited for removing the tank contents which should be transported in a watertight, closed container. Figure 7-9 shows a truck-mounted pump and tank assembled for this purpose.

TILE FIELDS

Tile fields of lines made of concrete or clay tile laid in the ground with open joints are used to dispose of settled sewage into the ground. A fiber pipe (Orangeburg Alkacid) or plastic pipe with holes bored in the lower portion of the pipe to allow drainage may be used for these drain lines. This pipe is light in weight and is easily laid in the trench. It comes in sizes ranging from 2 inches to 8 inches in diameter and in lengths from 5 feet to 8 feet. Because of these long lengths, this type of pipe is particularly valuable in soil where other types of pipe may settle unevenly. Figure 7-10 shows a typical field layout.


NOT OVER 75' LONG
5' TO 10'
SEWER FROM SETTLING TANKS WITH TIGHT JOINTS
6" TILE PIPE WITH OPEN JOINTS
PLAN
6" TOPSOIL IF SITUATION JUSTIFIES GRASSED SURFACE
EARTH BACK FILL
9" TO 20" OR AS REQUIRED
TAR PAPER OVER JOINTS
3" FINE-SCREENED GRAVEL ¼" TO ½"
3"
15"
6" TILE PIPE WITH OPEN JOINTS ¼" CLEAR SPACE AT JOINT
6"
COARSE-SCREENED GRAVEL 1" TO 2½"
THIS POINT NEVER BELOW GROUNDWATER IF POSSIBLE
1' TO 3'
TYPICAL SECTION (PROFILE)

54.390

Figure 7-10.—Typical layout of a subsurface tile system.

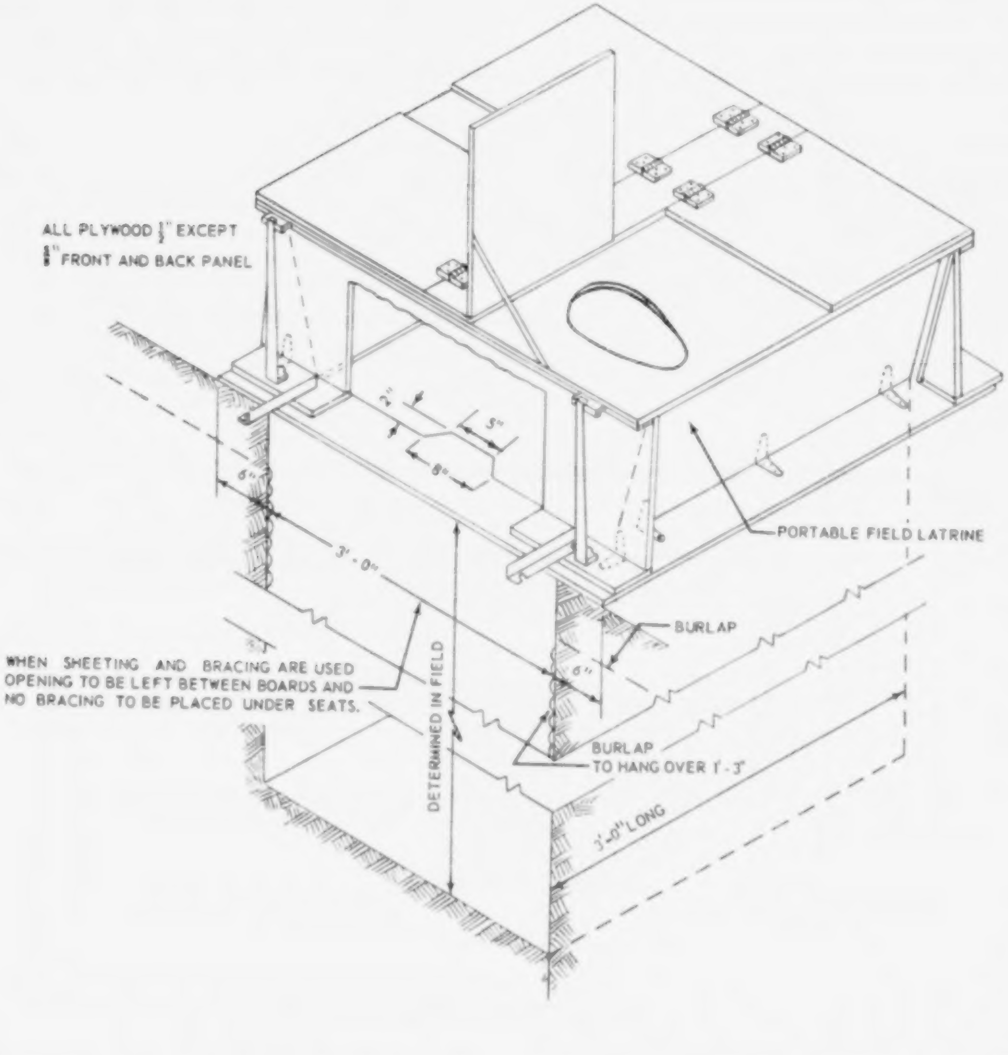
Proper Functioning

The following conditions are important for proper functioning of tile fields:

- Groundwater well below the level of the field
- Soil of satisfactory leaching characteristics within a few feet of the surface, extending several feet below the tile
- Subsurface drainage away from the field
- Adequate area
- Freedom from possibility of polluting drinking water supplies, particularly from shallow dug or driven wells in the vicinity

Tests

The length of tile and details of the filter trench generally depend upon the character of the soil. Soil leaching tests should be made at the site, as described for leaching cesspools, except the test hole should extend only to the approximate depth at which the tile lines are to be laid. For extensive tile fields, several tests to determine the best location and average conditions should be made.


ALL PLYWOOD ½" EXCEPT
⅝" FRONT AND BACK PANEL
2"
5"
8"
6"
3'-0"
PORTABLE FIELD LATRINE
BURLAP
6"
WHEN SHEETING AND BRACING ARE USED OPENING TO BE LEFT BETWEEN BOARDS AND NO BRACING TO BE PLACED UNDER SEATS.
DETERMINED IN FIELD
BURLAP TO HANG OVER 1'-3"
3'-0" LONG

133.189

Figure 7-11.—Prefabricated four-seat latrine box.

From test results, the rate of sewage application to the total bottom area of the tiled trenches may be taken from the data below. Soil testing over 30 minutes is not suitable.

Time for water to fall 1 inch (minutes)	Allowable rate of sewage application in gallons per square foot per day, bottom of trench in tile field
1	4.0
2	3.2
5	2.4
10	1.7
30	0.8

Trench Width

The minimum widths of trenches on the basis of soils are as follows:

- Sand and sandy loam, 1 foot
- Loam and sand and clay mixture, 2 feet
- Clay with some gravel, 3 feet

Frost Line

Placing tile below the frost line to prevent freezing is not necessary. Tile placed 18 inches below the ground surface operated successfully in New England for many years. Subsurface tile should never be laid below groundwater level.

Pipe Size

Design and construction should provide for handling and storage of some solid material, eliminating as much as practical the opportunity for clogging near pipe joints. Pipe 4 to 6 inches in diameter is recommended. The larger pipe gives greater storage capacity for solids and a larger area at the joint for solids to escape into the surrounding gravel.

Laying the Pipe

To provide for free discharge of solids from the line to the filter trench, lay the pipe with 3/8-inch clear openings. The top of the space is covered with tar paper or similar material to prevent entry of gravel. Bell-and-spigot pipe is easily laid to true line and grade. Good practice calls for breaking away two thirds along the bottom of the bells at the joint and using small wood-block spacers. The pipe is commonly laid at a slope of about 0.5 foot per 100 feet when taking the discharge directly from the septic tank and 0.3 foot per 100 feet when a dosing tank is used ahead of the field.

Beds

The tile is laid on a bed of coarse-screened gravel 6 inches deep with 3 inches of coarse gravel around and over the pipe. Coarse-screened stone passing 2 1/2-inch mesh and retained on a 3/4-inch mesh is recommended. This gravel bed gives a relatively large percentage of voids into which the solids pass and collect before the effective leaching area becomes seriously clogged. The soil that fills the trench must not fill the voids in the coarse-screened gravel around the pipe. A 3-inch layer of medium-screened gravel over the coarse stone and 3 inches of either fine-screened gravel or suitable bank-run gravel over the medium stone is recommended.

Layout

The layout of the tile in the field should be carefully designed. Generally, the length of laterals should NOT exceed 75 feet. When tile is laid in sloping ground, distribute the flow so each lateral gets a fair portion. Flow must be prevented from discharging down the slope to the lowest point. Individual lines should be laid nearly parallel to land contours. (See fig. 7-10.) Tile fields are commonly laid out either in a herringbone pattern or with the laterals at right angles to the main distributor. The distance between laterals is three times the width of the trench. Distribution boxes to which the laterals are connected may be desirable. Trenches, 24 inches wide or more, are economical. When a trenching machine is practical on a large installation, base the design on the width of the trench excavated by the machine.

Protecting the Field

Once a tile field is constructed, all traffic must be excluded by fencing or posting to prevent crushing the tile. Planting shrubs or trees over the field is not good practice since the roots tend to clog the tile lines; grass over the lines aids in removing the moisture and keeping the soil open. A typical section of a tile filter trench is shown in figure 7-8.

FIELD-TYPE LATRINES

Upon arrival at an advanced base, temporary facilities must be provided immediately for the disposal of human waste. A number of designs of field-type latrines are used for this purpose. A 16- by 32-foot wood-frame tent may be used to shelter the field-type latrine.

A prefabricated four-seat latrine box is shown in figure 7-11. This box can be collapsed for shipment, as indicated in figure 7-12.

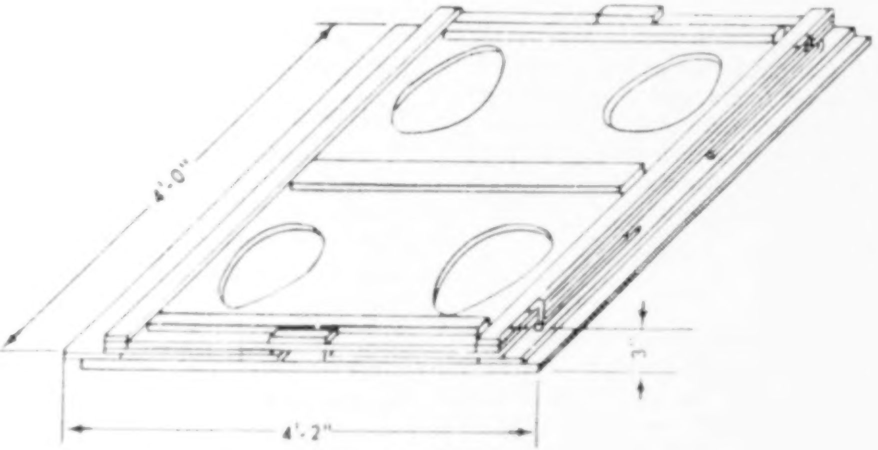
A plan view of an eight-seat field-type latrine is shown in figure 7-13. As indicated, the eight-seat field-type latrine can be expanded to a 16-seat latrine. With this type of latrine, two four-seat boxes are placed to straddle a 3- by 7-foot pit. After the pit is dug and before the boxes are placed, a 4-foot-wide margin around the pit is excavated to a depth of 6 inches, as shown in figure 7-14. A layer of oil-soaked burlap is laid in this excavation; then the excavated earth is soaked with oil, replaced, and tamped down to keep out surface water.

Two 4-foot 6-inch trough-type urinals are furnished with the eight-seat latrine. Each urinal is mounted in a frame constructed as shown in figure 7-15. A 2-inch urinal drainpipe leads from the downpipe on each urinal to a 6- by 6-foot urinal SEEPAGE PIT, located as shown in figure 7-15. The seepage pit is constructed as shown in figure 7-16.

A 4-inch hole burnout field-type latrine is used at most advanced or temporary bases. The burn-out latrine is kept in an orderly condition (daily) by the camp maintenance personnel or by an assigned sanitation crew. Two people can effectively and efficiently dispose of the excremental waste of 500 people. There are two easy ways of maintaining the burnout latrine. They are as follows: by spreading lime over the waste material or by using diesel fuel to burn the waste material. The burning pit for the waste material should be located so resulting smoke, fumes, odors, and blowing ashes do not interfere with operations or the health and well-being of personnel.

GALLEY WASTE

The wastewater in the galley sewer normally contains a large amount of grease. Therefore, a grease trap must be installed in the sewer system to intercept and collect grease. A typical grease trap, which can be constructed in Bravo company shops, is shown in figure 7-17. This trap allows grease to enter the sewer system, to congeal, and to float to the top of the barrels. As a minimum, the grease must be removed once daily from the trap and disposed of, usually by burning. A properly constructed and maintained grease trap



133.190

Figure 7-12.—Latrine box collapsed for shipment.

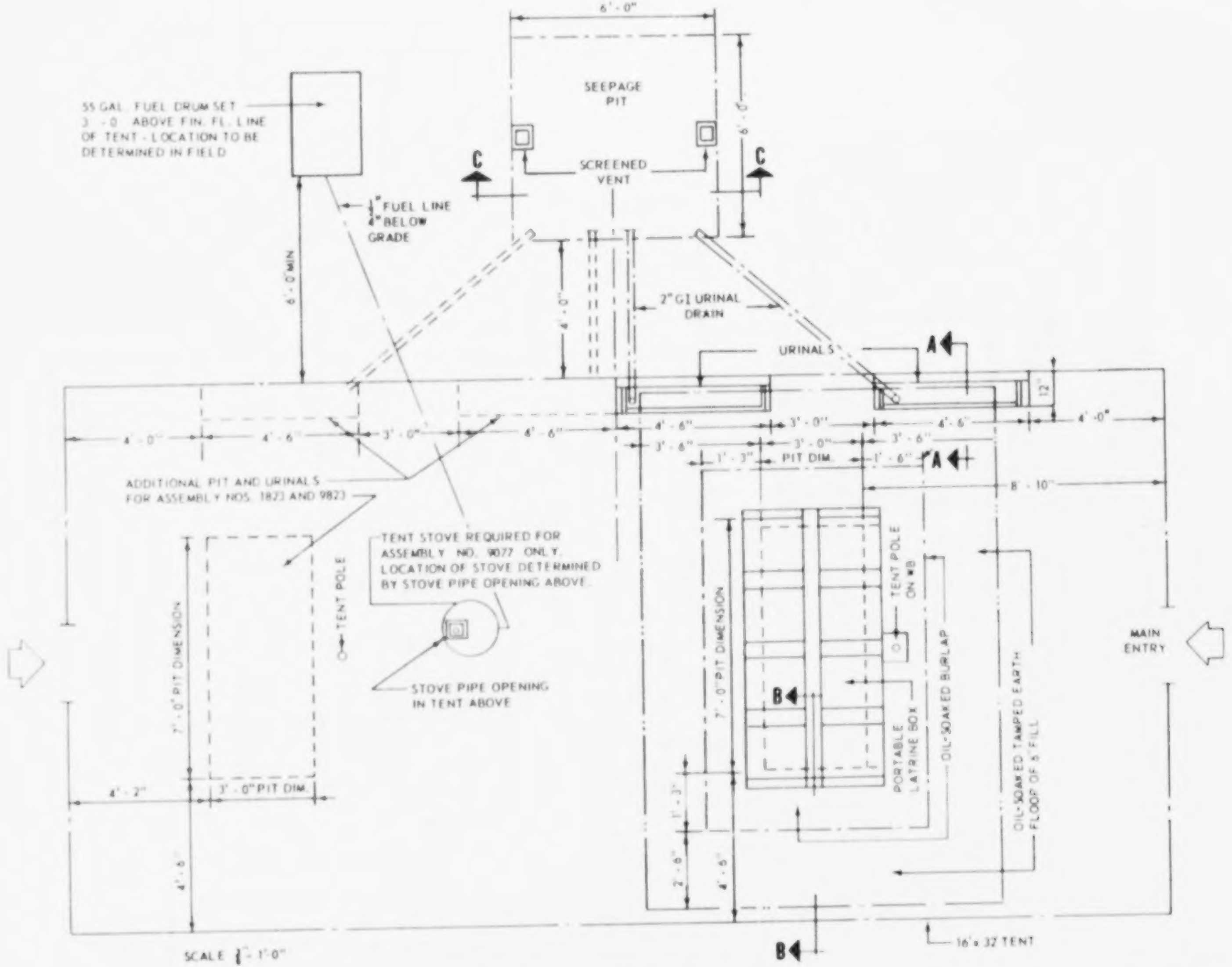
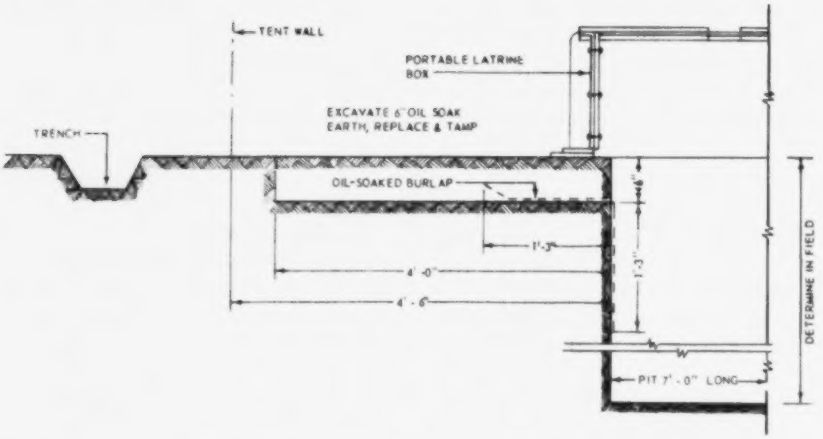

6'-0"
SEEPAGE PIT
6'-0"
SCREENED VENT
C
C
55 GAL. FUEL DRUM SET 3'-0" ABOVE FIN. FL. LINE OF TENT - LOCATION TO BE DETERMINED IN FIELD
½" FUEL LINE 4" BELOW GRADE
6'-0" MIN
4'-0"
2" GI URINAL DRAIN
URINALS
A
12"
4'-0"
4'-6"
3'-0"
3'-6"
3'-0"
4'-6"
3'-6"
1'-3"
PIT DIM.
1'-6"
A
8'-10"
4'-0"
4'-6"
3'-0"
4'-6"
ADDITIONAL PIT AND URINALS FOR ASSEMBLY NOS. 1823 AND 9823
TENT STOVE REQUIRED FOR ASSEMBLY NO. 9077 ONLY. LOCATION OF STOVE DETERMINED BY STOVE PIPE OPENING ABOVE.
TENT POLE
STOVE PIPE OPENING IN TENT ABOVE
7'-0" PIT DIMENSION
3'-0" PIT DIM.
4'-2"
4'-6"
7'-0" PIT DIMENSION
TENT POLE ON ¢B
B
PORTABLE LATRINE BOX
OIL-SOAKED BURLAP
OIL-SOAKED TAMPED EARTH FLOOR OF 6" FILL
MAIN ENTRY
1'-3"
2'-6"
4'-6"
B
16' x 32' TENT
SCALE ⅛" = 1'-0"

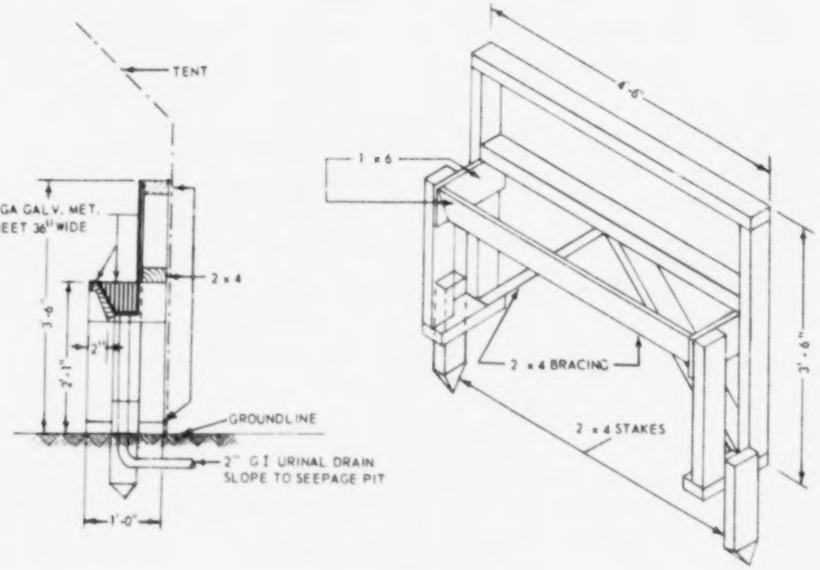
Figure 7-13.—Plan view of eight-seat field-type latrine.

133.191


TENT WALL
PORTABLE LATRINE BOX
EXCAVATE 6" OIL SOAK EARTH, REPLACE & TAMP
TRENCH
OIL-SOAKED BURLAP
6"
1'-3"
1'-3"
4'-0"
4'-6"
DETERMINE IN FIELD
PIT 7'-0" LONG

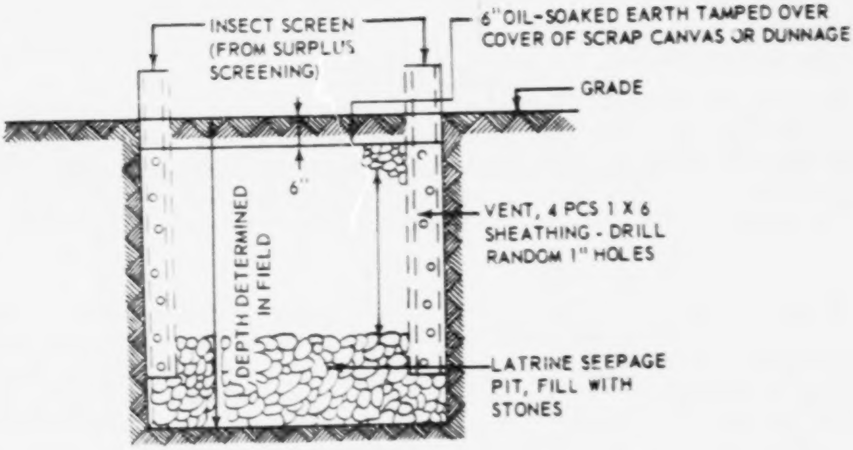
133.192

Figure 7-14.—Margin of oil-soaked earth around latrine boxes.


TENT
24-GA GALV. MET. SHEET 36" WIDE
2 x 4
3'-6"
2'-1"
2"
GROUNDLINE
2" G I URINAL DRAIN SLOPE TO SEEPAGE PIT
1'-0"
4'-6"
1 x 6
2 x 4 BRACING
3'-6"
2 x 4 STAKES

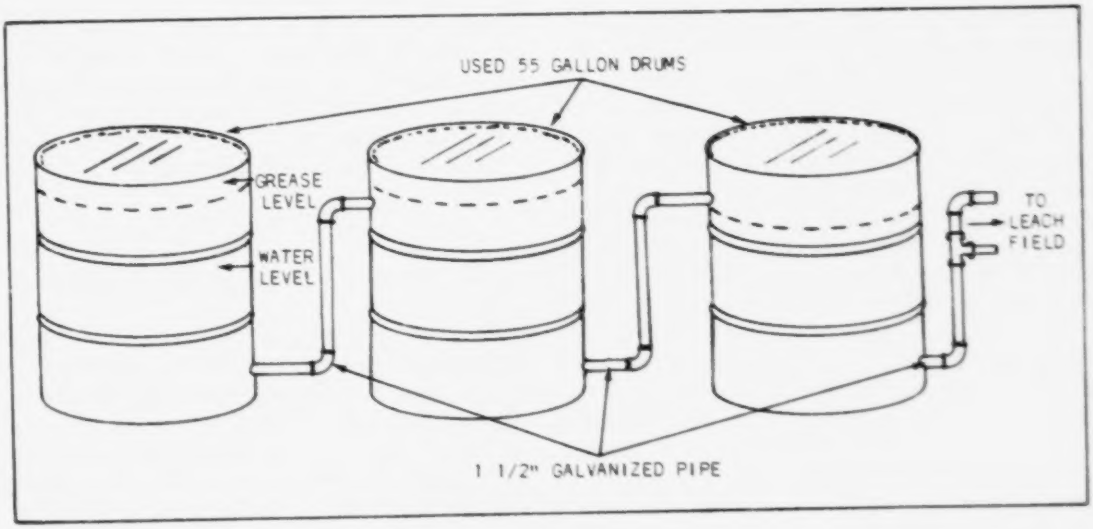
133.93

Figure 7-15.—Frame for urinal trough.


INSECT SCREEN
(FROM SURPLUS
SCREENING)
6" OIL-SOAKED EARTH TAMPED OVER
COVER OF SCRAP CANVAS OR DUNNAGE
GRADE
6"
DEPTH DETERMINED
IN FIELD
VENT, 4 PCS 1 X 6
SHEATHING - DRILL
RANDOM 1" HOLES
LATRINE SEEPAGE
PIT, FILL WITH
STONES

133.94

Figure 7-16.—Urinal seepage pit.


USED 55 GALLON DRUMS
GREASE
LEVEL
WATER
LEVEL
TO
LEACH
FIELD
1 1/2" GALVANIZED PIPE

54.579

Figure 7-17.—Field galley grease trap.

helps to ensure proper operation of the leach field that disposes of the wastewater.

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CHAPTER 8

BOILERS

Learning Objectives: Identify boiler design requirements, types of boilers and their purpose. Recognize boiler operation steps and checks, automatic controls, and procedures involved in fireside and waterside cleaning.

A BOILER is an enclosed vessel in which water is converted to steam by the burning of fuel and raised to the proper temperature and pressure necessary to serve its intended purpose.

A central heating plant may have one or more boilers that use gas, oil, or coal as fuel. The steam generated is used to heat buildings and to provide hot water and steam for cleaning, sterilizing, cooking, and laundering operations. Small heating boilers also provide steam and hot water for small buildings.

A careful study of this chapter can help you acquire useful knowledge of steam generation, types of boilers pertinent to SEABEE operations, various fittings commonly found on boilers, and so on. The main objective of this chapter is to lay the foundation for you to develop skill in the operation, maintenance, or repair of boilers.

STEAM GENERATION THEORY

To acquaint you with some of the fundamentals underlying the process of steam operation, suppose that you set an open pan of water on the stove and turn on the heat. You will find that the heat causes the temperature of the water to increase and, at the same time, to expand in volume. When the temperature reaches the BOILING POINT (212°F, or 100°C, at sea level), a physical change occurs in the water; the water starts vaporizing. When you hold the temperature at the boiling point long enough, the water continues to vaporize until the pan is dry. A point to remember is that THE TEMPERATURE OF WATER DOES NOT INCREASE BEYOND THE BOILING POINT. Even if you add more heat after the water starts to boil, the water cannot get any hotter, as long as it remains at the same pressure.

Now, suppose you place a close-fitting lid on the pan of boiling water. The lid prevents the steam escaping from the pan, and this results in a buildup of pressure inside the container. However, if you make an opening in the lid, steam escapes at the same rate it is generated. As long as water remains in the vessel and as long as the pressure remains constant, the temperature of the water and steam remains constant and equal.

The steam boiler operates on the same basic principle as a CLOSED CONTAINER OF BOILING WATER. By way of comparison, it is as true with the boiler as with the closed container, that steam formed in boiling tends to push against the water and sides of the vessel. Because of this downward pressure on the surface of the water, a temperature IN EXCESS of 212°F is required for boiling. The higher temperature is obtained simply by increasing the supply of heat. Bear in mind, therefore, that AN INCREASE IN PRESSURE MEANS AN INCREASE IN BOILING POINT TEMPERATURE.

There are a number of technical terms used in connection with steam generation. Here are some of the commonly used terms you should know.

"Degree" is defined as a measure of heat intensity. "Temperature" is defined as a measure in degrees of sensible heat. The term *sensible heat* refers to heat that can be measured with a thermometer.

Technically speaking, HEAT is a form of energy measured in British thermal units (Btu). One Btu is the amount of heat required to raise 1 pound of water 1 degree Fahrenheit at sea level.

Simply stated, the term *steam* means water in a vapor phase. DRY SATURATED STEAM is steam at the saturation temperature corresponding to pressure, and it contains no water in suspension. WET SATURATED STEAM is steam at the saturation temperature corresponding to pressure, and it contains water particles in suspension.

The QUALITY of steam is expressed in terms of percent. For instance, if a quantity of wet steam consists of 90 percent steam and 10 percent moisture, the quality of the mixture is 90 percent.

You know, of course, that all the water in a vessel, if held at boiling point long enough, will change into steam. What you may not know, is that there is a definite relationship between the pressure and temperature. AS LONG AS THE PRESSURE IS HELD CONSTANT, THE TEMPERATURE OF THE STEAM AND BOILING WATER REMAINS THE SAME.

SUPERHEATED STEAM is steam at a temperature higher than saturation temperature corresponding to pressure. For example, a boiler may operate at 415 psig (pounds per square inch gauge). The corresponding saturation temperature for this pressure is 445°F, and this will be the temperature of the water in the boiler and the steam in the drum. (Charts and graphs are available for computing this pressure-temperature relationship.) This steam can be passed through a superheater where the pressure remains about the same, but the temperature will be increased to some higher figure.

BOILER DESIGN REQUIREMENTS

A boiler must meet certain requirements before it is considered satisfactory for operation. Three important requirements are that the boiler (1) be safe to operate, (2) be able to generate steam at the desired rate and pressure, and (3) be economical to operate. Make it a point to familiarize yourself with the boiler code and other requirements applicable to the area in which you are located.

Here are a few rules set up by the ASME (American Society of Mechanical Engineers). These are general guidelines used by engineers when designing the boilers you use. For economy of operation and to generate steam at the desired rate and pressure, a boiler must have the following attributes:

Adequate water and steam capacity

Rapid and positive water circulation

A large steam generating surface

Heating surfaces that are easy to clean on both water and gas sides

Parts accessible for inspection

A correct amount and proper arrangement of heating surface

A firebox for efficient combustion of fuel

TYPES OF BOILERS

The Utilitiesman is concerned primarily with the FIRE-TUBE type of boiler, since it is the type generally used in SEABEE operations. However, the WATER-TUBE type of boiler may occasionally be used at some activities. The information in this chapter primarily concerns the different designs and construction features of fire-tube boilers.

The basis of identifying the two types is as follows:

WATER-TUBE BOILERS are those in which the products of combustion surround the tubes through which the water flows.

FIRE-TUBE BOILERS are those in which the products of combustion pass through the tubes and the water surrounds them.

WATER-TUBE BOILERS

Water-tube boilers may be classified in a number of ways. For our purpose, they are classified straight tube and bent tube. These two classes are discussed separately in succeeding sections. To avoid confusion, make sure you study carefully each illustration referred to throughout the discussion.

Straight Tube

The STRAIGHT-TUBE category of water-tube boilers includes three types: sectional-header cross drum, box-header cross drum, and box-header longitudinal drum.

In the SECTIONAL-HEADER CROSS DRUM boiler with vertical headers, the headers are steel boxes into which the tubes are rolled. Feedwater enters and passes down through the downcomers (pipes) into the rear sectional-headers from which the tubes are supplied. The water is heated and some of it changes into steam as it flows through the tubes to the front headers. The steam-water mixture returns to the steam drum through the circulating tubes and is discharged in front of the steam-drum baffle that helps to separate the water and steam.

Steam is removed from the top of the drum through the dry pipe. This pipe extends along the length of the drum and has holes or slots in the top half for steam to enter.

Headers, the distinguishing feature of this boiler, are usually made of forged steel and are connected to the drums with tubes. Headers may be vertical or at right angles to the tubes. The tubes are rolled and flared into the header. A handhole is located opposite the ends of each tube to facilitate inspection and cleaning. Its purpose is to collect sediment that is removed by blowing down the boiler.

Baffles are usually arranged so that gases are directed across the tubes three times before being discharged from the boiler below the drum.

BOX-HEADER CROSS DRUM boilers are shallow boxes made of two plates: a tube-sheet plate that is bent to form the sides of the box and a plate containing the handholes that is riveted to the tube-sheet plate. Some are designed so that the front plate can be removed for access to tubes. Tubes enter at right angles to the box-header and are expanded and flared in the same manner as the sectional-header boiler. The boiler is usually built with the drum in front. It is supported by lugs fastened to the box-headers. This boiler has either cross or longitudinal baffling, arranged to divide the boiler into three passes.

Water enters the bottom of the drum, flows through connecting tubes to the box-header, through the tubes to the rear box-header, and back to the drum.

BOX-HEADER LONGITUDINAL DRUM boilers have either a horizontal or inclined drum. Box-headers are fastened directly to the drum when the drum is inclined. If the drum is horizontal, the front box-header is connected to it at an angle greater than 90 degrees. The rear box-header is connected to the drum by tubes. Longitudinal or cross baffles can be used with either type.

Bent Tube

Boilers of this type usually have three drums. The drums are usually of the same diameter and positioned at different levels with each other. The uppermost or highest positioned drum is referred to as the STEAM DRUM, while the middle drum is referred to as the WATER DRUM, and the lowest, the MUD DRUM. The drums are connected by tube banks. The tubes are bent at the ends to enter the drums radially.

Water enters the top rear drum, passes through the tubes to the bottom drum, and then moves up through the tubes to the top front drum. A mixture of steam and water is discharged into this drum; steam returns to the top rear drum through the upper row of tubes, while the water travels through the tubes in the lower rear drum by tubes extending across the drum and enters a small collecting header above the front drum.

Many types of baffle arrangements are used with bent-tube boilers. Usually, they are installed so that 70 to 80 percent of the heat is absorbed by the inclined tubes between the lower drum and the top front drum.

The water-tube boilers discussed above offer a number of worthwhile advantages. For one thing, they afford flexibility in starting up. They also have a high productive capacity ranging from 100,000 to 1,000,000 pounds of steam per hour. In case of tube failure, there is little danger of a disastrous explosion of the water-tube boiler. The furnace not only can carry a high overload, it can also be modified for firing by oil or coal. Still another advantage is that it is easy to get into sections inside the furnace to clean and repair them.

There are also several disadvantages common to water-tube boilers. One of the main drawbacks of water-tube boilers is their high construction cost. The large assortment of tubes required of this boiler and the excessive weight per unit weight of steam generated are other unfavorable factors.

FIRE-TUBE BOILERS

There are four types of fire-tube boilers: the Scotch marine boiler, the vertical-tube boiler, the horizontal return tubular boiler, and the firebox boiler. These four types of boilers are discussed in this section.

Scotch Marine Boiler

The SCOTCH MARINE fire-tube boiler is especially suited to SEABEE needs. (See fig. 8-1.) It is a portable unit and can be moved with ease and with a minimum of foundation work. As a complete self-contained unit, its design includes automatic controls, steel boiler, and burner equipment. These features are a big advantage because no disassembly is required when you have to take the boiler to the field for emergency work or have to move it to a more suitable location in the area.

The Scotch marine boiler has a two-pass (or more) arrangement of tubes that run horizontally to allow the heat inside the tubes to travel back and forth. It also has an internally fired furnace with a cylindrical combustion chamber. There is a flue-gas outlet, or smoke breeching, located on the front end of the boiler. Oil is the fuel commonly used to fire the Scotch boiler. Where desirable, though, it can be fired by gas, coal, or wood.

One advantage that the Scotch boiler has over the water-tube boiler is that it requires less space and can be set up in a low-ceiling room. Then, too, its tubes are all the same size. This saves time and trouble in making tube replacements.

The Scotch boiler also has a few disadvantages. Its shell runs from 6 to 8 feet in diameter, a detail of construction that makes a large amount of reinforcing necessary. Too, the fixed dimensions of its internal furnace cause some difficulty in cleaning the surfaces of the section below the combustion chamber. Another drawback is the limited capacity and pressure of the Scotch boiler.

The SETTING of the Scotch boiler is self-supporting. The shell rests in two or more steel cradles, and the boiler is sometimes pitched slightly to aid in draining the boiler. The setting includes a blowdown pipe that is connected to the bottom of the shell which, in turn, is screwed into a pad riveted to the shell.

In a two-way Scotch boiler, the gases flow toward the rear of the combustion chamber, then return by way of the tubes to the front, and out into the smokebox and stack breeching.

An important safety device sometimes used is the fusible plug which provides added protection against low water. In case of low water, the plug core melts and steam escapes, and a loud noise results, warning the operator. On the Scotch boiler, the fusible plug usually is located in the crown sheet, but sometimes it is found in the

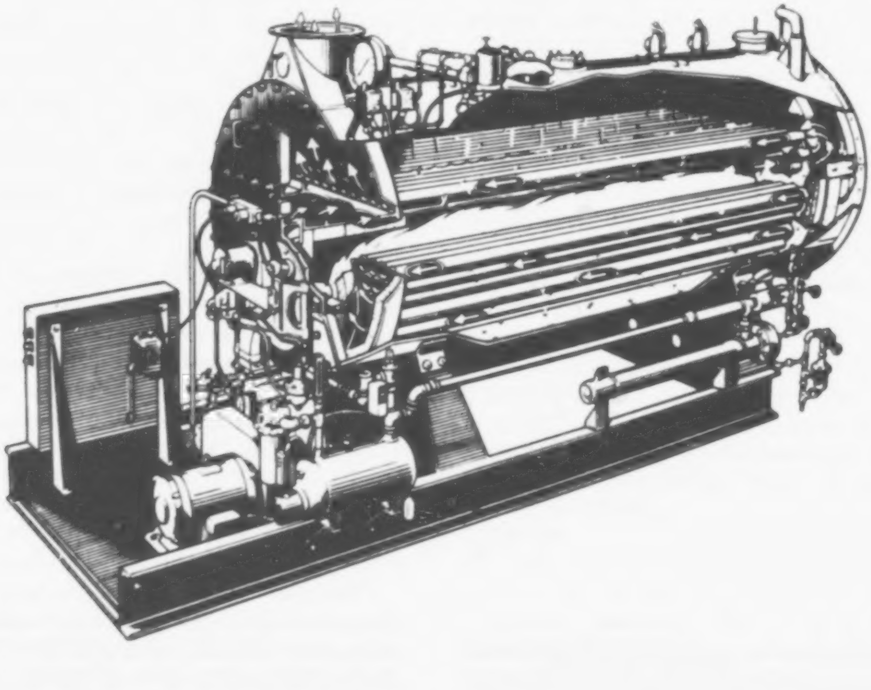

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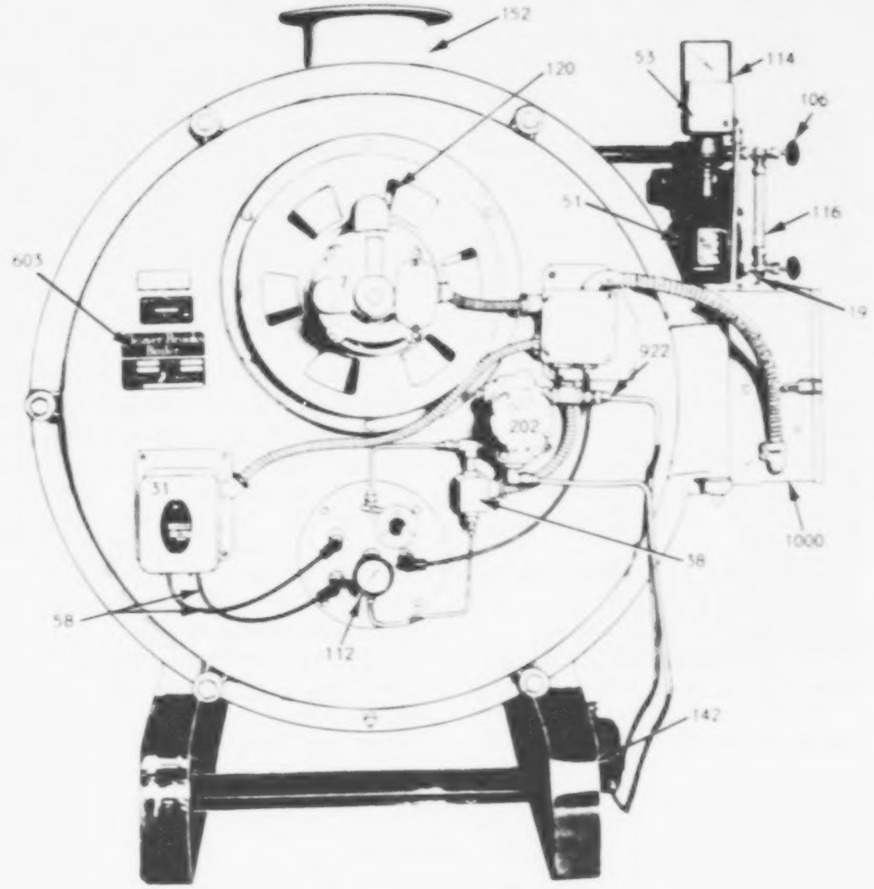
Figure 8-1.—Scotch marine type fire-tube boiler.



7. Blower Motor.
19. Burner Switch.
31. Ignition Transformer.
38. Solenoid Oil Valve (Maint).
51. Low-Water Control.
53. High-Limit Pressure Control.
58. Ignition Cable.
106. Gauge Glass Shutoff Cock.
112. Fuel Oil Pressure Gauge.
114. Steam Pressure Gauge.
116. Water Level Gauge.
120. Air Damper.
142. Fuel Oil Supply Connection.
152. Vents.
202. Oil Unit, Two Stage.
603. Nameplate.
922. Priming Tee.
1000. Service Connection Box.

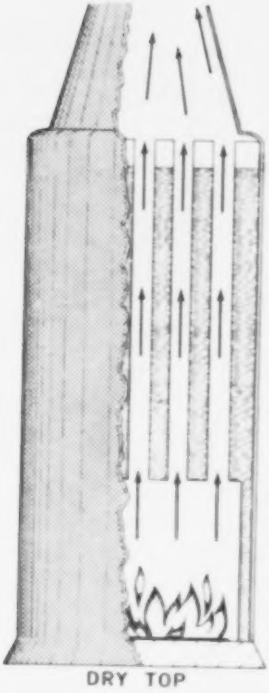
54.506

Figure 8-2.—Low-pressure boiler.

upper back of the combustion chamber. (Types of fusible plugs are discussed later in this chapter.)

Accesses for cleaning, inspection, and repair of the boiler watersides are provided through a manhole in the top of the boiler shell and a handhole in the water leg. The MANHOLE is an opening large enough for a man to enter the boiler shell for inspection, cleaning, and repairs. On such occasions, always make sure all valves are secured, locked, and tagged, and that the person in charge knows you are inside the boiler shell. Also, have someone stationed at the outside entrance for aid. The HANDHOLE is an opening large enough to permit hand entry for cleaning, inspection, and repairs to headers and tubes.

Figure 8-2 shows a horizontal fire-tube boiler used in low-pressure applications. Boilers of this



54.582
Figure 8-3.—Cutaway view of vertical fire-tube boiler.

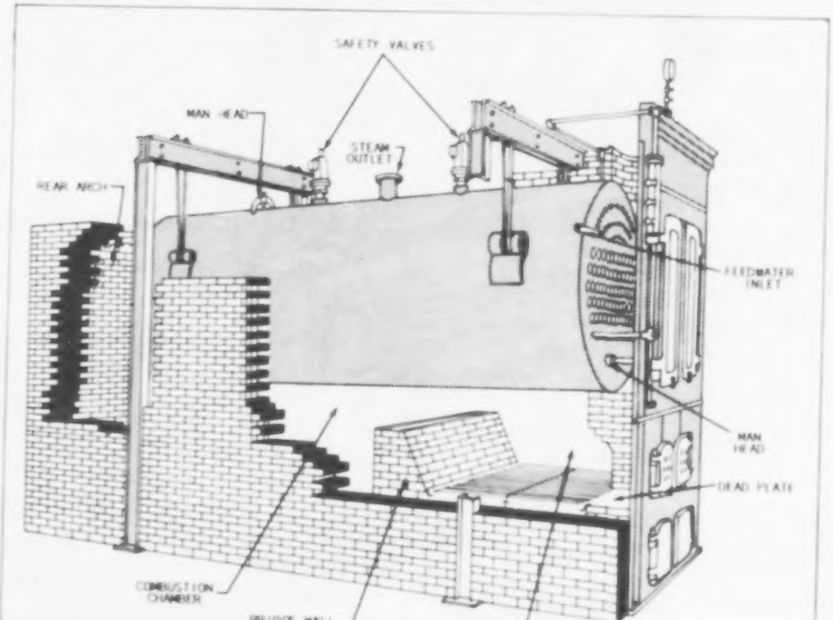
type are probably the most commonly encountered by a Utilitiesman.

Vertical-Tube Boiler

In some fire-tube boilers, the tubes run vertically, as opposed to the horizontal arrangement in the Scotch boiler. The VERTICAL-TUBE boiler sits in an upright position as indicated in figure 8-3. Therefore, the products of combustion (gases) make a single pass, traveling straight up through the tubes and out the stack.

The vertical fire-tube boiler is similar to the horizontal fire-tube boiler in that it is a portable, self-contained unit requiring a minimum of floor space. Handholes are also provided for cleaning and repairing. Though self-supporting in its setting (no brickwork or foundation being necessary), it MUST be level. The vertical fire-tube boiler has the disadvantage of a limited capacity and furnace volume as does the horizontal-tube design.

Before selecting a vertical fire-tube boiler, you must know how much overhead space is in the building where it will be used. Since this boiler sits in an upright position,


SAFETY VALVES
MAN HEAD
STEAM OUTLET
REAR ARCH
FEEDWATER INLET
MAN HEAD
DEAD PLATE
COMBUSTION CHAMBER
BRIDGE WALL
FURNACE

54.115
Figure 8-4.—Horizontal return tubular (HRT) fire-tube boiler.

a room with a high ceiling is necessary for its installation.

The blowdown pipe of the vertical fire-tube boiler is attached to the lowest part of the water leg, and the feedwater inlet opens through the top of the shell. The boiler fusible plug is installed either (1) in the bottom tube sheet or crown sheet or (2) on the outside row of tubes, one-third the height of the tube from the bottom.

Horizontal Return Tubular Boiler

In addition to operating portable boilers, such as the Scotch marine and vertical fire-tube boilers, the Utilitiesman must also be able to operate stationary boilers, both in the plant and in the field. A STATIONARY BOILER can be defined as one having a permanent foundation and not easily moved or relocated. A popular type of stationary fire-tube boiler is the HORIZONTAL RETURN TUBULAR (HRT) boiler, shown in figure 8-4.

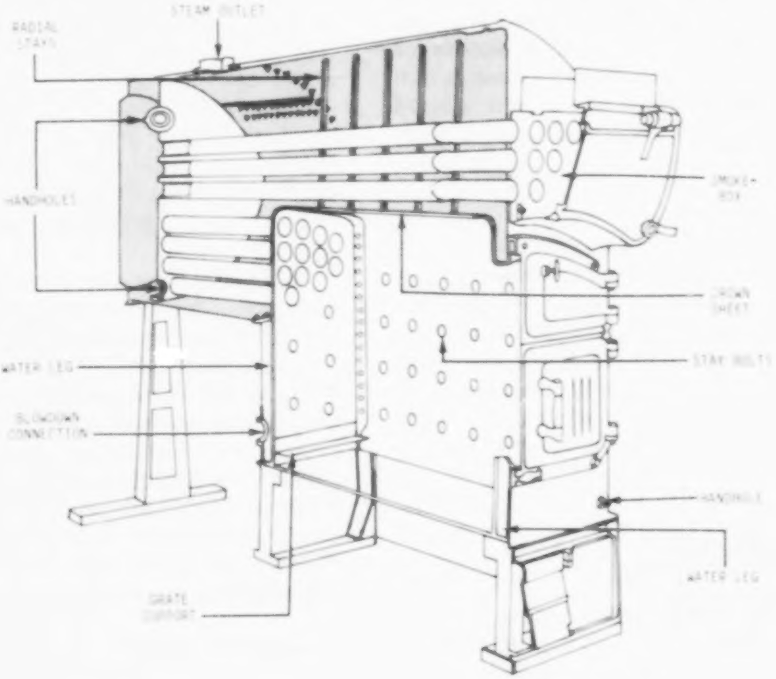
The initial cost of the HRT boiler is relatively low, and installing it is not too difficult. The boiler setting can be readily changed to meet different fuel requirements—coal, oil, wood, or gas. Tube replacement is also a comparatively easy task since all tubes in the HRT boiler are the same in size, length, and diameter.

The gas flows in the HRT boiler from the firebox to the rear of the boiler, then returns through the tubes to the front where it is discharged to the breeching and the stack.

The HRT boiler has a pitch of 1 to 2 inches to the rear to allow sediment to settle toward the rear near the bottom blowdown connection. The fusible plug is located 2 inches above the top row of tubes. Boilers over 40 inches in diameter require a manhole in the upper part of the shell. Those over 48 inches in diameter must have a manhole in the lower, as well as in the upper part of the shell. Do not fail to familiarize yourself with the location of these and other essential parts of the HRT boiler. The knowledge you acquire will definitely help in the performance of your duties with boilers.

Firebox Boiler

Another type of fire-tube boiler is the FIREBOX boiler which generally is used for stationary purposes. A split section of a small firebox boiler is shown in figure 8-5. Gases in the



54.116

Figure 8-5.—Split section of a small firebox boiler.

firebox boiler make two passes through the tubes. Firebox boilers require no setting, except possibly an ash pit for coal fuel. As a result, they can be quickly installed and placed in service. Gases travel from the firebox through a group of tubes to a reversing chamber and return through a second set of tubes to the flue connection on the front of the boiler and are discharged up the stack.

BOILER PARTS AND FITTINGS

By now you should have a general idea of the overall basic structure of a boiler. A number of questions probably have come to mind as to the importance of certain boiler parts and the operation or function of various devices, such as controls, valves, try cocks, and the like. That brings us to the topic of PARTS AND FITTINGS. A sufficient number of essential boiler parts and fittings are discussed in this section to provide a background for further study. As a reminder, and in case you should run across some unit or device not covered in this text, check the manufacturer's manual for information on details of its construction and method of operation (where applicable).

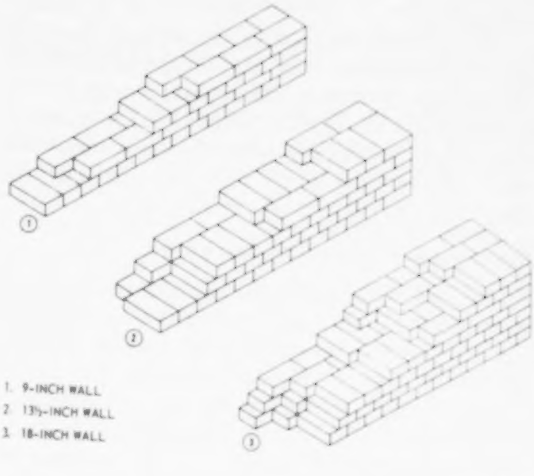
The term *fittings* includes various controlling devices on the boiler. Bear in mind, therefore, that fittings are vitally important to economy of operation and safety of personnel and equipment. You must understand fittings if you are to acquire skill in the installation, operation, and servicing of steam boilers.

SETTINGS

The SETTING is the structure that encloses the boiler and forms the furnace. It may also support all or part of the boiler. The self-supported type of setting is common. The outer wall is built of hard-burned brick. The inner wall is built of firebrick to withstand high temperatures. Several examples of this type of setting are pictured in figure 8-6.

CHIMNEYS, DRAFT FANS, AND BREECHINGS

Chimneys are necessary for discharging the products of combustion at an elevation high enough to comply with health requirements and to prevent a nuisance because of low-flying smoke, soot, and ash. A boiler needs a draft to mix air correctly with the fuel supply and to conduct the flue gases through the complete setting.



54.119

Figure 8-6.—Furnace sidewall construction.

The air necessary for combustion of fuel cannot be supplied normally by a natural draft. Therefore, draft fans may be used to ensure that the air requirements are properly met. Two types of draft fans used on boilers are forced-draft and induced-draft fans. They are damper controlled and usually are driven by an electric motor.

The FORCED-DRAFT fan forces air through the fuel bed, or fuel oil burner, and into the furnace to supply air for combustion. The INDUCED-DRAFT fan draws gases through the setting, thus facilitating their removal through the stack.

Breechings are used to connect the boiler to the stack. They are usually made of sheet steel with provision for expansion and contraction. The breeching may be carried over the boilers, in back of the setting, or even under the boiler room floor. Keep breechings as short as possible and free from sharp bends and abrupt changes in area. The cross-sectional area should be approximately 20 percent greater than that of the stack to keep draft loss to a minimum. A breeching with a circular cross section causes less draft loss than one with a rectangular or square cross section.

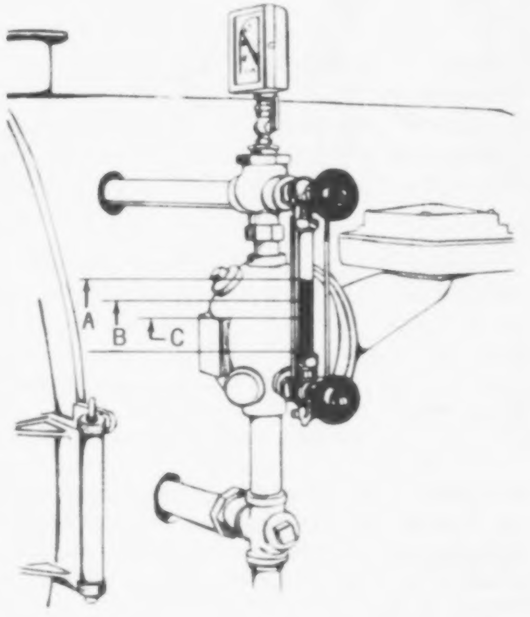
GAUGE GLASSES

Each boiler must have at least one WATER-GAUGE GLASS; if the operation pressure is 400 psi or more, two gauge glasses must be provided.

The gauge glass indicates the water level in the steam drum. Each gauge glass must have a valve drain, and the gauge glass and pipe connections must not be less than 1/2-inch pipe size. The lowest visible part of the water gauge must be at least 2 inches above the lowest permissible water level. This is defined as the lowest level at which there is no danger of overheating any part of the boiler when in operation at that level. Horizontal fire-tube boilers are set to allow at least 3 inches of water over the highest point of the tubes, flues, or crown sheet at the lowest reading in the gauge glass.

The water-gauge glass shown in figure 8-7 is used with a boiler operating at low or medium pressure. Each type of boiler has a strong glass tube connected to the boiler or water column by two special fittings. These fittings sometimes have an automatic shutoff device, usually a nonferrous ball that functions if the water glass fails. The automatic shutoffs must be made according to certain provisions of the boiler code. The following are some of these provisions: The top ball must be capable of completely shutting off the flow; the bottom ball must rise vertically to the seat; the balls must be accessible for inspection; and provisions must be made to permit the removal and inspection of the bottom ball while the boiler is in service.

Unless two gauge glasses are installed on the same horizontal line, each boiler must have three or more gauges or try cocks (figs. 8-8 and 8-9) located within the visible length of the gauge glass. Boilers require only two cocks when they are not over 36 inches in diameter and their heating surface does not exceed 100 square feet. Gauge cocks are used to check the accuracy of the gauge glass. They are opened by a handwheel, chain wheel, or lever, and are closed by hand, by a weight, or by a spring.



A. High Level of Water: 2 inches above bottom of gauge. Boiler feed pump or water feeder turns off at this point. Fill initially to this height.

B. Low Level of Water: 1 1/4 inches above bottom of gauge. Boiler feed pump or water feeder turns on at this point to restore water level to 2 inches.

C. Low Water Cutoff Point: 1/2 inch above bottom of gauge. Burner turns off at this point.

54.507

Figure 8-7.—A water level controller and gauge glass.

WATER COLUMN

A WATER COLUMN is a hollow vessel having two connections to the boiler. (See fig. 8-9.) The top connection enters the steam drum of the boiler through the top of the shell or drum. The water connection enters the shell or head at least 6 inches below the lowest permissible water level. The purpose of the water column is to steady the water level in the gauge glass through the reservoir capacity of the column. Also, the column may eliminate the obstruction on small diameter, gauge-glass connections by serving as a sediment chamber.

The water columns shown are equipped with high- and low-water alarms that sound a whistle to warn the operator. The whistle is operated by either the two floats or the solid weights shown in figure 8-9.

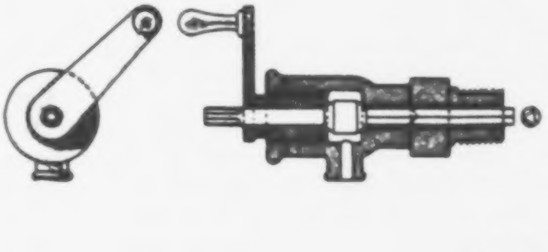


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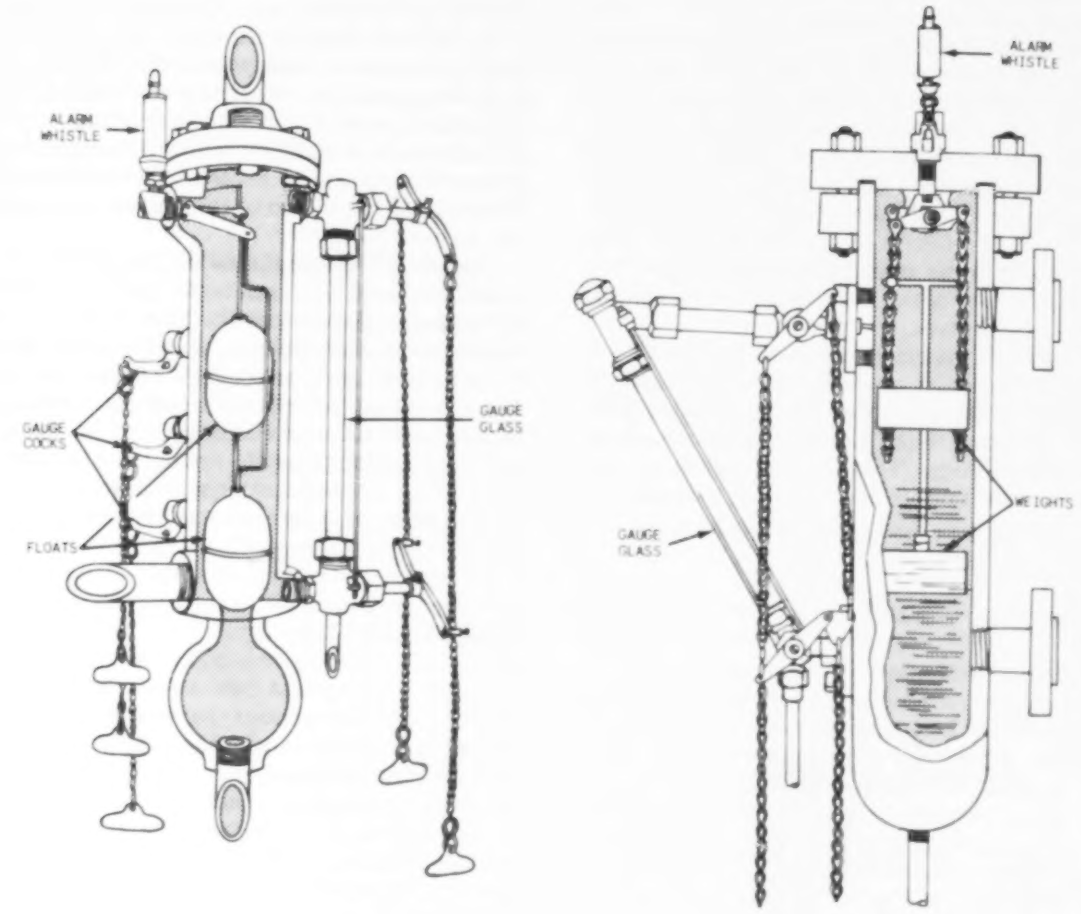
Figure 8-8.—Try cock.



54.122

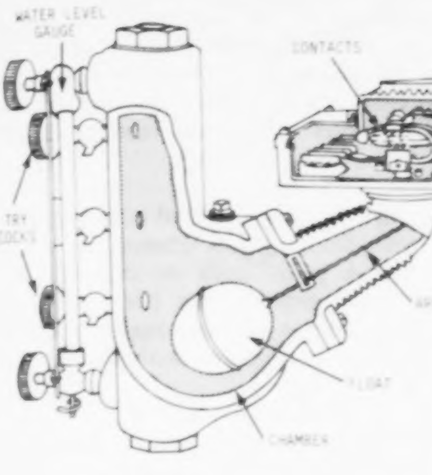
Figure 8-9.—Typical water columns.

WATER LEVEL CONTROL

The water level control not only automatically operates the boiler feed pump but also safeguards the boiler against low water by stopping the burner. Various types of water level controls are used on boilers. At SEABEE activities, boilers frequently are equipped with a float-operated type, a combination float and mercury switch type, or an electrode probe type of automatic water level control. Each of these types is described below.

The FLOAT-OPERATED TYPE of feedwater control, similar in design to the feedwater control shown in figure 8-10, is attached to the water column. This control uses a float, arm, and a set of electrical contacts. As a low-water cutoff, the float rises or lowers with the water level in an enclosed chamber. The chamber is connected to the boiler by two lines which allow the water and steam to have the same level in the float chamber as in the boiler. An arm and linkage connects the float to a set of electrical contacts that operate the feedwater pump when the water lowers the float. If the water supply fails or the pump becomes inoperative and allows the water level to continue to drop, another set of contacts operates an alarm bell, buzzer, or whistle, and secures the burners.

The COMBINATION FLOAT AND MERCURY SWITCH TYPE of water level control (fig. 8-10) reacts to changes made within a maintained water level by breaking or making a complete control circuit to the feedwater pump. It is a simple two-position type control, having no



54.123

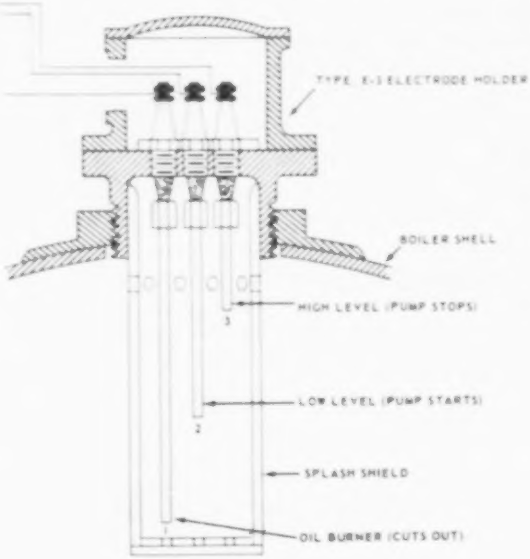
Figure 8-10.—Combination float and mercury switch type of feedwater control.

modulation or differential adjustment or setting. As all water level controllers should be, it is wired independently from the programmer. The control is mounted at steaming water level and consists of a pressurized float, a pivoted rocker arm, and a cradle-attached mercury switch.

The combination float and mercury switch type of water level control functions as follows: As the water level within the boiler tends to drop, the float lowers. As the float lowers, the position of the mercury switch changes. Once the float drops to a predetermined point, the mercury within the tube runs to its opposite end. This end contains two wire leads, and when connected through the puddle of mercury, completes a circuit to the feedwater pump. The pump, being energized, admits water to the boiler. As the water level within the boiler rises, the float rises. As the float rises, the position of the mercury switch changes. Once the float rises to a predetermined point, the mercury runs to the opposite end of its tube, breaking the circuit between the wire leads and securing the feedwater pump. The feedwater pump remains off until the water level again drops low enough to trip the mercury switch.

The ELECTRODE PROBE TYPE of feedwater regulating and low-water cutoff control consists of an electrode assembly and a water level relay. The electrode assembly contains three electrodes of different lengths corresponding to high, low, and cutoff water level in the boiler drum. (See fig. 8-11.)

The electrode assembly is installed on the top of the boiler drum so the normal water level is at approximately the midpoint between the high-level and the low-level electrodes. The electrodes are electrically wired to the water level relay assembly. The relay contains the feedwater pump start and stop contacts wired to the feedwater pump controller and the low-water cutoff contacts wired into the burner circuit. The feed pump is started when the water level in the boiler drops below the middle electrode. After the water level is restored and reaches the high-level electrode, the feed pump is stopped. If the water level is not restored and drops below the longest electrode, the cutoff contacts of the water level relay stop the burner by breaking the burner circuit. The electrodes are held in position by screwing them into a threaded connector, located at the top of the electrode bottle. In some cases, they also are locked in position with a suitable locking device; however, this is not a design feature common to all installations. Boiler casualties have occurred from low-water cutoff electrodes backing off from threaded connectors and grounding with the assembly bottle. On those installations where one is not present, a locking device should be installed.



75.299

Figure 8-11.—Electrode type of water level control.

PRESSURE GAUGES

Each boiler is equipped with a PRESSURE GAUGE that measures pressure. There are several types of pressure gauges in common use, including the Bourdon-tube gauge shown in figure 8-12.

The Bourdon tube is made of seamless metal tubing and is oval in cross section. The tube is bent in the form of the letter *C*. One end of the tube is open and is connected to a socket that opens into the pressure line leading to the gauge. The other end of the Bourdon tube is closed and is free to move; this free end is connected to the gauge pointer by a linkage system of levers and gears. The position of the free end of the Bourdon tube represents a balance between two forces: the pressure of the liquid or gas inside the Bourdon tube which tends to straighten the tube and the spring action of the metal which tends to coil the tube. When the pressure in the line increases, the tube straightens out slightly and the free end moves away from the center. This movement operates the linkage system and moves the pointer to a higher reading on the dial. When the pressure in the line decreases, the free end of the Bourdon tube moves toward the center and moves the pointer to a lower reading on the dial.

The gauge should be tested semiannually, or whenever there is any reason to doubt its accuracy. A gauge cock or shutoff valve will be installed between the pressure gauge and pressure source so the pressure gauge can be removed or repaired without relieving pressure in the boiler.

A pressure gauge must be accurately calibrated and have a loop of tubing, called a siphon (or pigtail), between the boiler and the gauge. (See fig. 8-13.) The exposed (uninsulated) coil is provided in the line leading to the gauge, and the steam condenses into water in this exposed coil. Thus, there is always a condensate seal between the gauge and steam source. Sometimes the condensate seal is lost when repairs are made to the

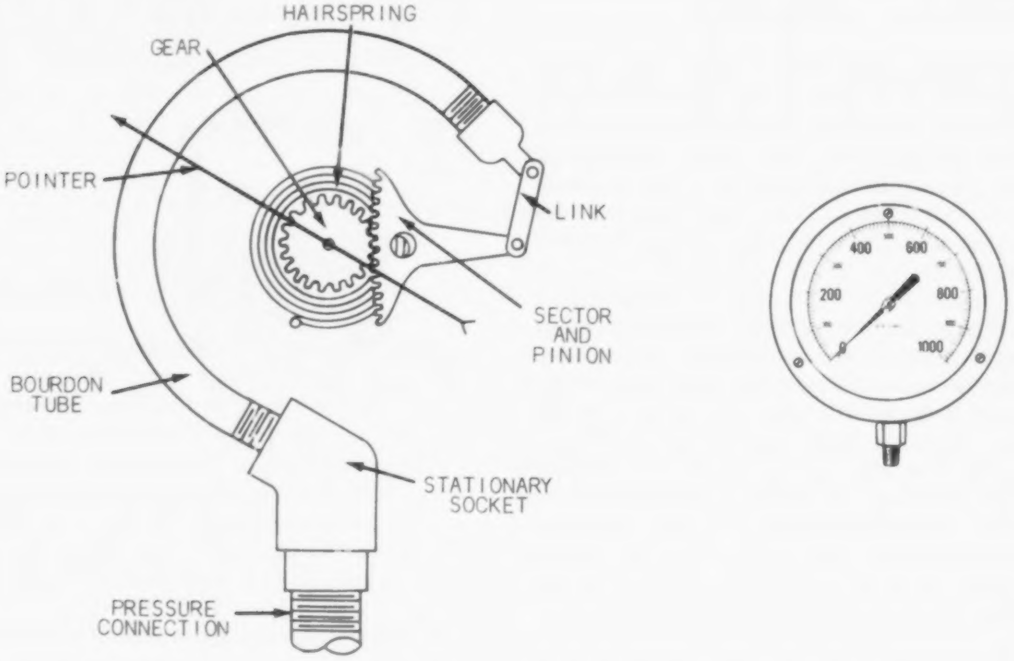


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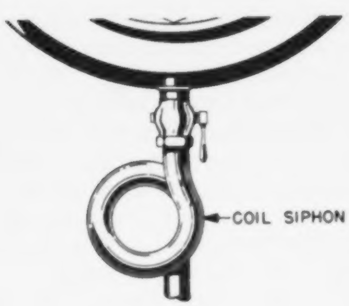
Figure 8-12.—Bourdon-tube pressure gauge.



54.124

Figure 8-13.—Siphon (or pigtail).

gauge or to the gauge line; in this event, the loop must always be filled with water before the gauge is subjected to steam line pressure.

FUSIBLE PLUGS

FUSIBLE PLUGS are used on some boilers to provide added protection against low water. They are constructed of bronze or brass with a tapered hole drilled lengthwise through the plug. They have an even taper from end to end. This tapered hole is filled with a low-melting alloy consisting mostly of tin. There are two types of fusible plugs: fire actuated and steam actuated.

The FIRE-ACTUATED plug is filled with an alloy of tin, copper, and lead with a melting point of 445°F to 450°F. It is screwed into the shell at the lowest permissible water level. One side of the plug is in contact with the fire or hot gases, and the other side is in contact with the water. As long as the plug is covered with water, the tin does not melt. When the water level drops below the plug, the tin melts and the steam blows the fire out. The boiler then must be taken out of service to replace the plug.

The STEAM-ACTUATED plug is installed on the end of a pipe outside the drum. The other end of the pipe, which is open, is at the lowest permissible water level in the steam drum. A valve is usually installed between the plug and the drum. The metal in the plug melts at a temperature below that of the steam in the boiler. The pipe is small enough to prevent water from circulating in it. The water around the plug is much cooler than the water in the boiler as long as the end of the pipe is below the water level. However, when the water level drops below the open end of the pipe, the cool water runs out of the pipe and steam heats the plug. The hot steam melts and blows the tin out, warning the operator. This type of plug can be replaced by closing the valve in the plug line. It is not necessary to take the boiler out of service to replace the plug.

Fusible plugs should be renewed regularly once a year. Do NOT refill old casings with new tin alloy and use again. ALWAYS USE A NEW PLUG.

VALVES

Boiler fittings include various types of valves, and each type is designed to serve a special purpose. With that thought in mind, some of the more common types of valves, their location, and their function are discussed below.

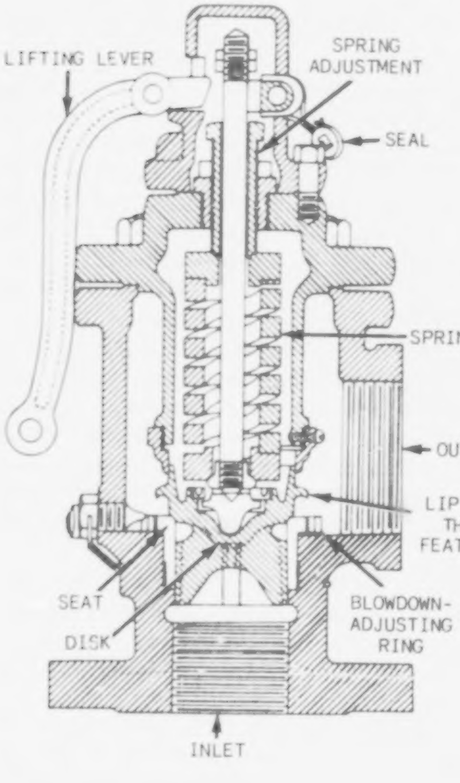
The MAIN STEAM STOP VALVE is located at the steam outlet of the boiler. The bearing surfaces on the valve disk and seat are usually made of a very hard erosion-resisting alloy, called STELLITE. Drain connections are sometimes fitted to the underside of the valve body, on either side of the valve disk. These drains can be used as bypass valves to equalize the pressure on both sides of the disk to facilitate opening of the main steam stop valve and to ensure proper drainage of that section of the main steam line. The main steam stop valve is either fully open or fully closed. The purpose of this valve is to put the boiler on the line or to secure it.

A FEED STOP VALVE and a STOP CHECK VALVE are installed on Navy boilers for shutting off the flow of feedwater and for controlling the flow of feed as desired. Check valves are located between the feed stop valve and the feed pump to eliminate any possible back pressure on the feed pump and condensate tank.

The SURFACE BLOW VALVE (when installed) is located on the steam drum where it connects to the surface blowline which terminates at a scum pan inside the drum. This pan is located just below the normal waterline. Its purpose is to remove scum from the surface of the water. As with most high-pressure valves of the globe type, the pressure is directed under the seat to facilitate opening.

BOTTOM BLOW VALVES, installed at the bottom of each water drum and header, are used to blow down the boiler, removing scale and other foreign matter that have settled in the lowest part of the water spaces. Boilers are also blown down to control concentration of solids dissolved in boiler water. Blowdown valves are located at the lowest point of the watersides.

The SAFETY VALVE, shown in figure 8-14, is the most important of boiler fittings. It is designed to open automatically to prevent pressure in the boiler from increasing beyond the safe operating limit. It is installed in a vertical position directly to the steam space of the boiler. Each boiler has at least one safety valve; if the boiler has more than 500 square feet of heating surface, two or more valves are required. There are several different types of safety valves in use, but all are designed to open completely (POP) at a specific pressure and to remain open until a specified pressure drop (BLOWDOWN) has occurred. Safety valves must close tightly, without chattering, and must remain tightly closed after seating.



54.508
Figure 8-14.—A typical spring-loaded safety valve.

It is important to understand the difference between boiler safety valves and ordinary relief valves. The amount of pressure required to lift a relief valve increases as the valve lifts, because the resistance of the spring increases in proportion to the amount of compression. When a relief valve is installed on a steam drum, therefore, it opens slightly when the specified pressure was exceeded; a small amount of steam is discharged; and then the valve closes again. Thus a relief valve on a steam drum is constantly opening and closing; this repeated action pounds the seat and disk and causes early failure of the valve. Safety valves are designed to open completely at a specified pressure to overcome this difficulty.

Several different types of safety valves are used on boilers, but they all lift on the same general principle. In each case, the initial lift of the valve disk, or feather, is caused by static pressure of the steam acting upon the disk, or feather. As soon as the valve begins to open, however, a projecting lip or ring of larger area is exposed for the steam pressure to act upon. The resulting increase in force overcomes the resistance of the spring, and the valve pops; that is, it opens quickly and completely. Because of the larger area now presented, the valve reseats at a lower pressure than that which caused it to lift originally.

Lifting levers are provided to lift the valve from its seat (when boiler pressure is at least 75 percent of that at which the valve is set to pop), to check the action, and to blow away any dirt from the seat. When the lifting lever is used, raise the valve disk sufficiently to ensure that all foreign matter is blown from around the seat to prevent leakage after being closed.

The various types of safety valves differ chiefly as to the method of applying compression to the spring, the method of transmitting spring pressure to the feather, or disk, the shape of the feather, or disk, and the method of blowdown adjustment. Detailed information on the operation and maintenance of safety valves can be found in the instruction books furnished by the manufacturers of this equipment.

The AIR COCK VALVE is located at the highest point of the steam space. Two important purposes of this valve are to allow air to escape while raising steam on a cold boiler or when filling a boiler with water and to allow air to enter when draining a boiler. When lighting off a cold boiler, the air cock valve is one of the first to open.

It is closed when sufficient steam has been generated to displace all the air in the steam space.

The ROOT VALVE is an emergency shutoff valve located between the source of pressure and the supplied equipment. An example is the valve located between the main steam stop valve and the main steam line. This valve must withstand maximum operating pressure.

STEAM INJECTOR FEED SYSTEM

The STEAM INJECTOR is a boiler FEED PUMP that uses the velocity and condensation of a jet of steam from the boiler to lift and force a jet of water into the boiler. This injection of water is many times the weight of the original jet of steam.

The injector is used to some extent in boiler plants as an emergency or standby feed unit. It does not feed very hot water. Under the best conditions, it will lift 120°F of water about 14 feet.

The installation of an injector is not a difficult operation. The unit is mounted on the side of the boiler. Four connections (fig. 8-15) are made to the injector (fig. 8-16): the steam supply line from the boiler, the water supply line from a reservoir, the discharge line to the boiler feedwater inlet, and the water overflow line.

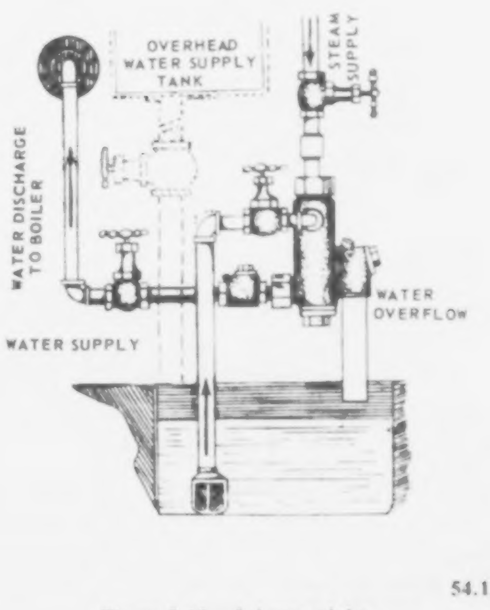


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Figure 8-15.—Injector piping.

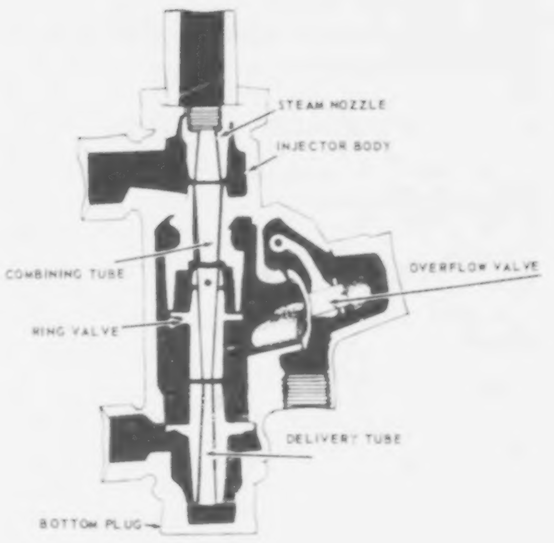

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Figure 8-16.—A cross-sectional view of an injector.

The controls include a steam supply valve, water supply valve, discharge valve to the boiler, and a check valve in the discharge line.

As you might expect, some degree of skill is needed to start the injector. After the injector begins to operate, however, it continues automatically until shutdown by the operator. When starting the injector, first open the water supply valve about one full turn. Next, quickly turn the steam supply valve all the way open. At this point, steam rushes into the combining tube of the injector. As the steam speeds past the water supply opening, it creates a suction that draws water through the opening into the combining tube. Water and steam are now mixed together inside the injector and the pressure opens a valve that leads to the boiler. Meanwhile, there is an excess of water in the injector; this excess is discharged through an overflow valve. As the next step of the procedure, slowly turn the water supply valve toward the closed position until the overflow stops. The overflow valve has now closed and all of the water being picked up from the supply line is going into the boiler. Remember, this feedwater system is used on boilers as a standby method of feeding water.

The water supply should not be hotter than 120°F for the injector to operate. In case several unsuccessful attempts are made to operate the injector, it becomes very hot and cannot be made to prime. If you should encounter this problem, pour cold water over the injector until it is cool enough to draw water from the supply when the steam valve is opened.

AUTOMATIC CONTROLS

Automatic controls are a big asset since they reduce manual control of the furnace, boilers, and auxiliary equipment. Four types of controls the Utilitiesman should become familiar with are as follows: float control, pressure control, combustion control, and flame failure and operation controls.

FLOAT CONTROL

The float in a boiler control works on the same basic principle as the float in a flush-tank type of water closet. Float, or level control, depends on the level of fluid in a tank or boiler to indicate the balance between the flow out of and the flow into the equipment and to operate a controller to restore the balance.

A float is often used to measure the change in fluid level and to operate the controlled valve to restore the balance. It may be arranged to increase the flow when the fluid level drops. Figure 8-17 shows one of the methods used to accomplish this. Here the float is connected to the control valve.

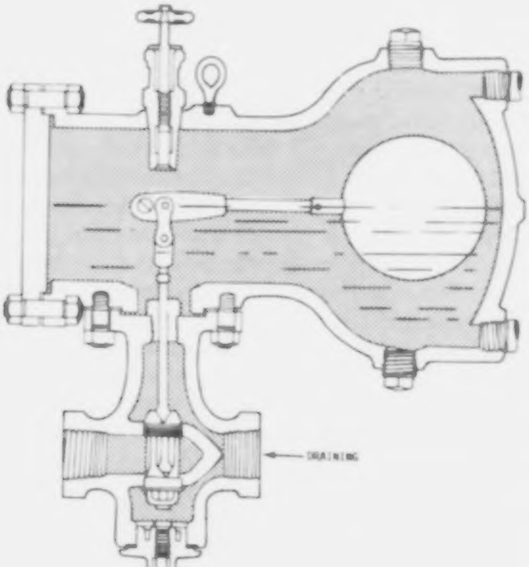

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Figure 8-17.—Float controller.

PRESSURE-REGULATING CONTROL

Pressure regulating is the process of maintaining a difference of pressure between two points in the system. One type of pressure regulating maintains a definite pressure in one part of the system, while the other part fluctuates or changes within certain limits. An example of this type of control is a pressure-reducing valve that maintains a definite pressure on the discharge side of the valve by controlling the flow of steam, air, or gas through the valve. (See fig. 8-18.)

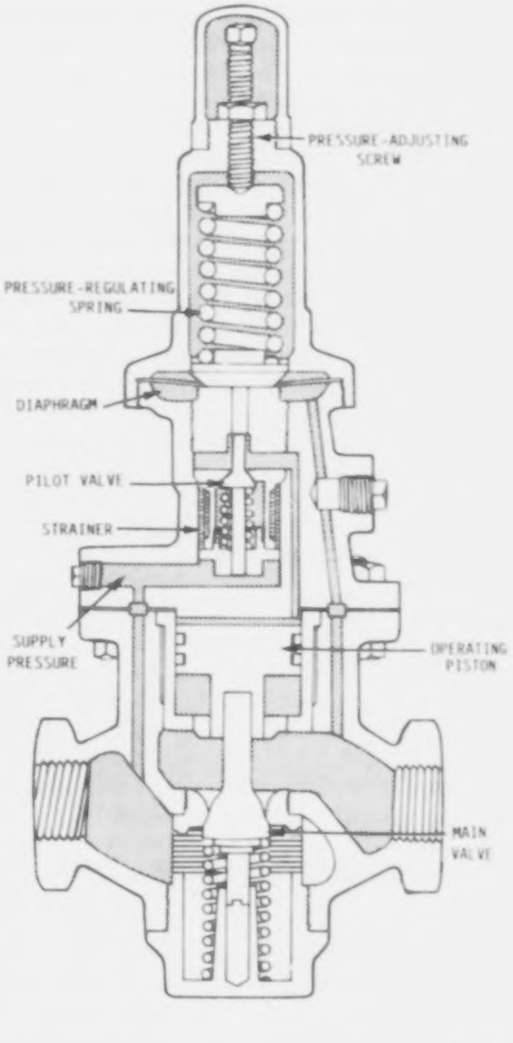

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Figure 8-18.—Pressure regulator.

A second type of regulator maintains a definite difference in pressure between two points and also controls the flow. This type of regulator is often applied to boiler feeding to maintain a fixed difference between the pressure of water supplied at the feed valve and the pressure in the boiler steam drum. The pressure regulator may consist of a self-contained device that operates the regulating valve directly, or it may consist of a pressure-measuring device, such as a Bourdon-tube gauge that operates a pilot or relay valve. The valve positions the regulating valve or mechanism to maintain the desired conditions.

Pressure controls (fig. 8-19) are designed primarily for steam-heating systems, but are also available for controlling air, liquids, or gases that are not chemically injurious to the control. The purpose of the pressure control is to control the pressure in the boiler, to secure the fuel-burning equipment when the pressure reaches a predetermined cutout, and to start the fuel-burning equipment when the pressure drops to the cut-in point. There are two settings on the pressure control: the cut-in point and the differential. To find the cutout point, you add the differential to the cut-in pressure; for example, if you were operating a boiler with a cut-in pressure of 90 pounds and a differential of 13 pounds, the cutout pressure should be 103 pounds. When excessive vibrations are encountered, you should mount the pressure control remotely from the boiler on a solid mounting with a suitable piping connection between them.

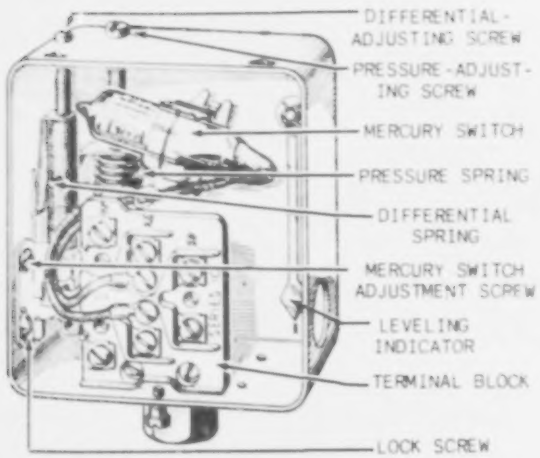

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Figure 8-19.—Typical pressure control with a differential from 0 to 10 pounds.

When a mercury type of switch control is used, be sure that it is mounted level and that the siphon (pigtail) has the loop extending in the direction of the back of the control and at a 90 degree angle to the front, as shown in figure 8-20. This prevents expansion and contraction of the siphon from affecting the level and accuracy of the control.

The pressure control can be mounted either on a tee along with the pressure gauge on the pressure-gauge tapping, as shown in figure 8-20, or it can be mounted on the low-water cutout provided by some manufacturers. In either case, be sure that the pipe dope is not permitted to enter the control. You apply the dope to the male threads, leaving the first two threads bare.

COMBUSTION CONTROL

Combustion control is the process of regulating the mixed flow of air and fuel to a furnace as necessary to supply the demand for steam. A modulating pressuretrol controls the movement of the modutrol motor which, in turn, opens or closes the oil valve and air shutters to adjust the rate of firing to suit the demands of

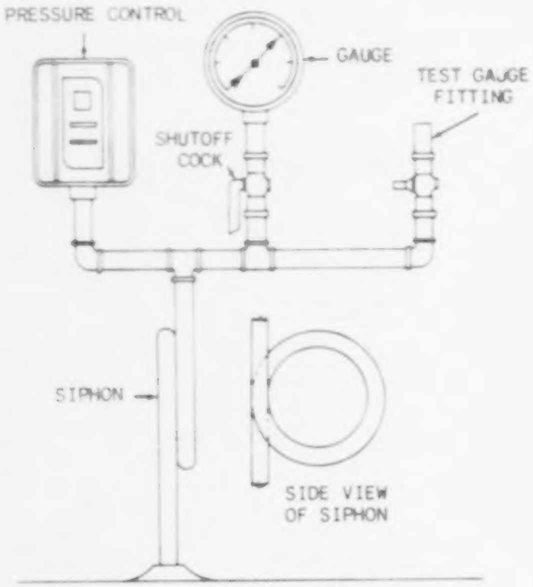

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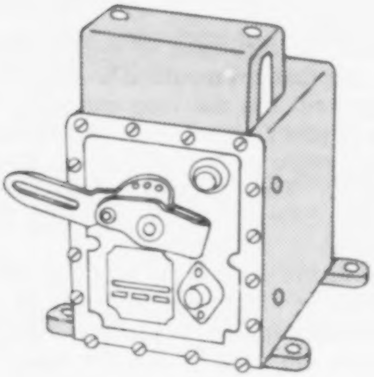
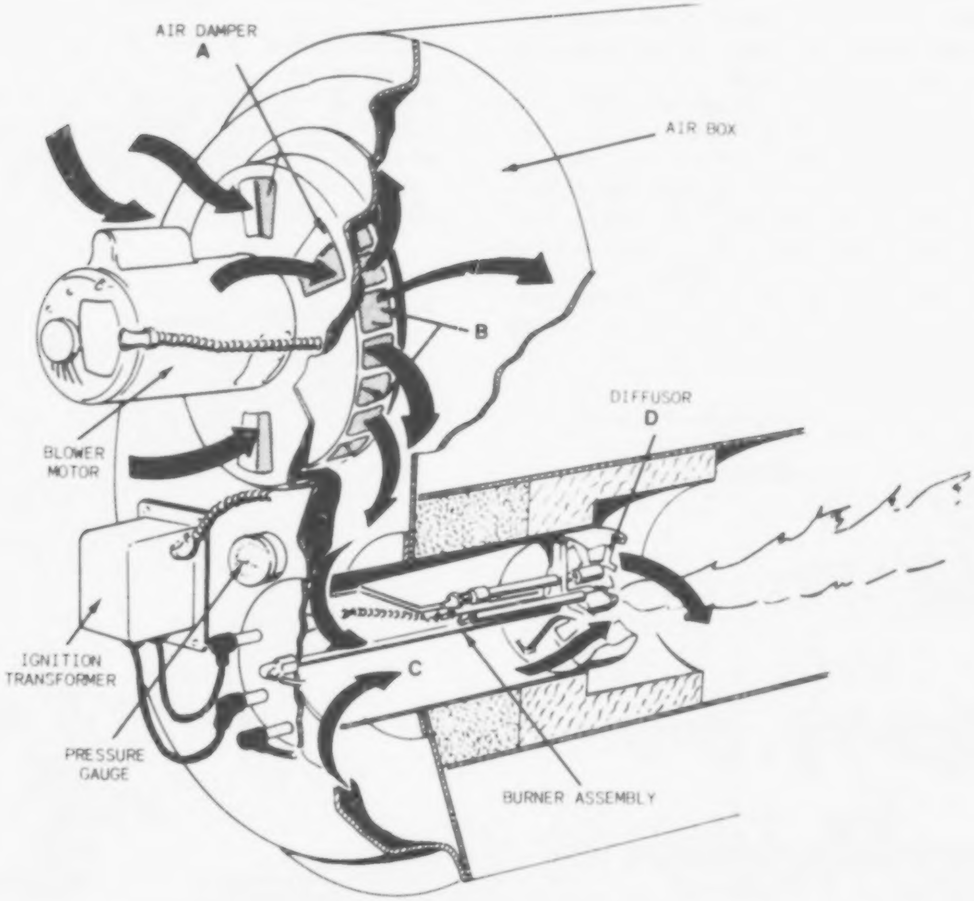
Figure 8-20.—A typical steam gauge installation.



54.133

Figure 8-21.—Modulating motor.

the boiler. Figure 8-21 shows a modulating motor. The modulating motor consists of the motor windings, a balancing relay, and a balancing potentiometer. The loading is transmitted to the winding through an oil-immersed gear train from the crank arm. The crankshaft is the double-ended type, and the crank arm may be mounted on either end of the motor. The motor works with the potentiometer coil in the modulating pressuretrol. An electrical imbalance is created by pressure change signals to the pressuretrol. This causes the motor to rotate in an attempt to rebalance the circuit. The crank arm, through linkage, positions the burner air louvers and the oil-regulating valve, maintaining a balanced flow of air and oil throughout the burner firing range.


AIR DAMPER
A
AIR BOX
B
DIFFUSOR
D
BLOWER MOTOR
IGNITION TRANSFORMER
C
PRESSURE GAUGE
BURNER ASSEMBLY

54.510

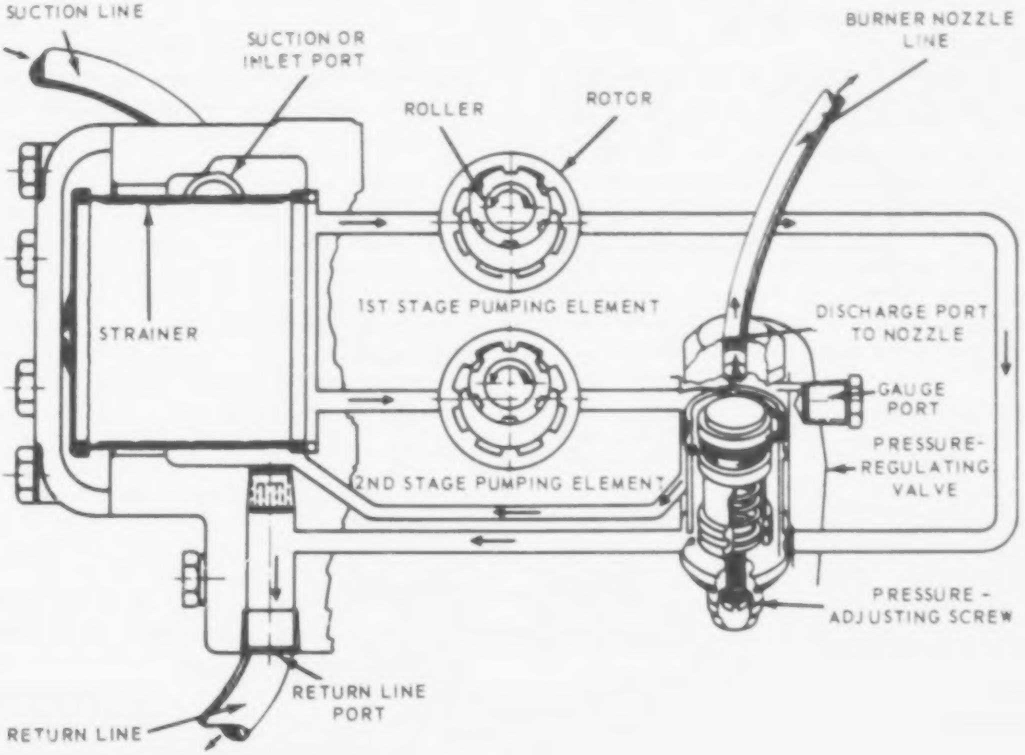
Figure 8-22.—Airflow diagram.

Another process of controlling combustion air is to use a manually adjusted air damper, as shown in figure 8-22. Combustion air is furnished by a centrifugal blower mounted on the boiler head and driven by the blower motor. A definite amount of air must be forced into the combustion chamber to mix with the atomized oil to obtain efficient combustion. In operation, a pressure is built up in the entire head and the secondary air is forced through a diffuser to mix thoroughly with the atomized oil as combustion takes place.

The combustion airflow diagram in figure 8-22 shows a cutaway view of those components that influence most the path of the air through the burner assembly. Air is drawn into the motor-driven blower through the adjustable air damper at (A) and forced through openings (B) into the air box. Sufficient pressure is built up to force the air through openings (C) and the diffusor (D). In the area immediately beyond the diffusor (D), combustion is completed. The hot gaseous products of combustion are forced on through the remaining three passes where they give up a large portion of the heat contained to the water which completely envelopes the passes. Refer to the cutaway view showing the four-pass construction.

The rate at which combustion air is delivered can be changed by throttling the intake to the blower by opening or closing the air damper (A) to obtain the exact rate of airflow required for complete combustion. Since the rate at which fuel is delivered is predetermined by the design and is not readily adjustable, setting of the air damper is the only means of obtaining the correct ratio of fuel to air to ensure the most efficient combustion. The fuel on this type burner is controlled by a pressure-regulating valve built into the pump, as shown in figure 8-23.

The fuel pump contains a two-stage gear-type pump, a suction strainer, a pressure-regulating valve, and a nozzle cutoff valve, all assembled in a single housing. A knowledge of the functional relationship of the component parts can be gained


SUCTION LINE
SUCTION OR INLET PORT
ROLLER
ROTOR
BURNER NOZZLE LINE
STRAINER
1ST STAGE PUMPING ELEMENT
DISCHARGE PORT TO NOZZLE
GAUGE PORT
PRESSURE-REGULATING VALVE
2ND STAGE PUMPING ELEMENT
PRESSURE-ADJUSTING SCREW
RETURN LINE PORT
RETURN LINE

54.511

Figure 8-23.—Fuel oil pump.

by studying the internal oil flow diagram (fig. 8-24).

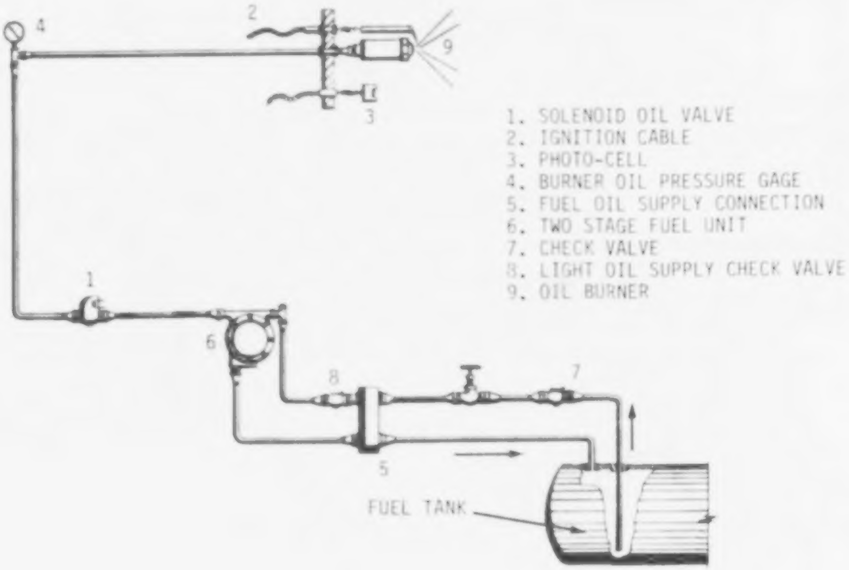
Observe that the two-stage fuel unit consists essentially of two pumps operating in tandem and arranged in a common housing. The first stage develops a pressure below the atmospheric pressure level at its inlet that causes the oil to flow from storage or supply to the strainer chamber reservoir. All air drawn into the unit rises to the top of this chamber. This air and excess oil are drawn into the first-stage pumping element and pumped back to the fuel oil storage tank. The second stage withdraws air-free oil from the strainer chamber reservoir and raises the oil pressure to that required for proper atomization at the burner nozzles. The second stage, operating against a combination pressure-regulating and nozzle cutoff valves, develops atomizing pressure because of the flow restriction imposed by this valve. The pressure-regulating valve also bypasses excess second-stage oil back to the bottom of the strainer chamber reservoir. The atomizing pressure can be varied within a restricted range by adjustment of the spring-loaded pressure-regulating valve. Normal atomizing pressures generally range between 95 and 120 pounds per square inch.

It should be noted that an orifice is included in the fuel line to the main oil burner (302) in figure 8-24; it serves to keep the oil pressure from experiencing a sudden drop when the solenoid oil valve in that line opens. This orifice is commonly built into the solenoid valve.

Included in the schematic diagram is a photocell (59) which, if it sights no flame, reacts to cause a switching action that results in shutting down the burner.

FLAME FAILURE AND OPERATION CONTROLS

Frequently, on fully automatic boilers, you will find an electronic type of device provided for the control of flame failure. The device provides automatic start and operation of the main burner equipment. Some controls are designed to close all fuel valves, shut down the burner equipment within 4 seconds after a flame failure, and actuate an alarm. Some controls also create a safety shutdown within 4 seconds after de-energization of ignition equipment when the main burner flame is not properly established or fails during the normal starting sequence. These controls must create a safety shutdown when the pilot flame is not established and confirmed within 7 seconds after lighting. A safety shutdown requires manual reset before operation can be resumed and prevents recycling of the burner equipment.



54.512

Figure 8-24.—The internal oil flow diagram.

In all initial starts and subsequent restarts, during on-and-off cycling, the automatic operation controls are designed to provide the following services:

- Low fire start. Precombustion and postcombustion scavenging, except for fully automatic boilers having capacities of 2,000 pounds per hour or less, that require no postcombustion scavenging (during precombustion or postcombustion scavenging periods, the blower should be on, and the ignition, pilot, and main fuel valve should be off).

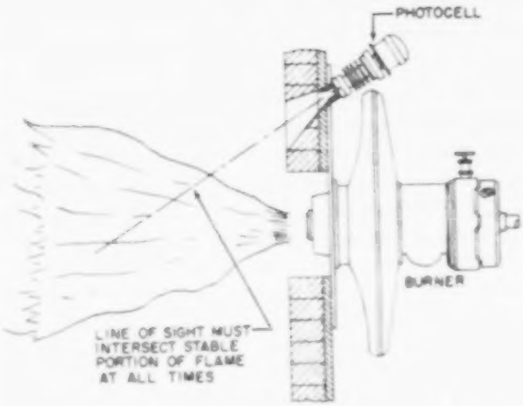
- Time delay of at least 5 seconds between ignition of the pilot and opening of the main fuel valve (except for gas-fired boilers and light oil-fired boilers with pilot, the pilot flame must be established and confirmed before opening of the main fuel valve).

- Trial-for-main-burner-ignition period. Note that the trial-for-ignition period is the time the pilot flame and/or ignition is on after the main fuel valve opens.

- Proper shift of operation from operating control to the combustion operating controls after the main burner flame has been properly established and confirmed.

- In case of supply voltage failure, the operating control recycles when power is restored. The electronic device should readily detect flame under all firing conditions of both pilot and main flame, but should not be actuated by hot refractory or any other hot body. The controls are designed so that failure of any vacuum tube or other component causes a safety shutdown or results in a safety interlock to prevent recycling of the control.

A typical and modern combustion safety device is the electronic type using a photocell (or electric eye) to detect the presence of an oil flame. (See fig. 8-25.) This is a fast-acting device and is referred to by such names as flame eye, scanner, and electric eye. The photocell reacts to the light of the oil flame, thereby allowing current to flow in the electronic circuit and holding the flame relay in a closed position. A failure of the flame interrupts the electronic circuit causing the burner to shut down on safety. The photocell is provided with a time delay of 4 to 8 seconds to prevent nuisance shutdowns because of fluctuations in flame, especially at low-fire positions.


PHOTOCELL
BURNER
LINE OF SIGHT MUST INTERSECT STABLE PORTION OF FLAME AT ALL TIMES

54.134

Figure 8-25.—Photocell (electric eye).

BOILER OPERATING LOGS

The main purpose of boiler operating logs is to record continuous data on boiler plant performance. Logs become a source of information for analyzing the boiler's operation for maintenance and repair. The daily operating log sheets provide the basic information around which maintenance programs are developed. The log is arranged for use over a 24-hour period divided into three 8-hour shifts. Log sheets vary among different activities, but you should have no difficulty in making log entries once you understand what information is required. The discussion below gives you an idea of the types of information to be entered in the appropriate column of the log as indicated in each paragraph.

- Steam pressure. These entries are based on steam gauge readings and indicate the boiler's performance.

- Steam flow. Record actual output of the plant in pounds per hour to obtain steam flow. The data from these entries are used to determine the number of boilers to operate for greatest efficiency.

- Feedwater heater pressure. Indicates whether the proper deaerating temperature can be maintained in the heater.

- Feedwater heater temperature. This temperature shows the effectiveness of the feedwater heater. A drop in steam-supply pressure or insufficient venting may cause low heater temperature.

- Feed pump pressure. This entry indicates the effectiveness of boiler feed pumps. If the feedwater supply fails, the pressure reading enables the operator to determine whether the trouble is in the feed pumps. Pumps are defective when the feed pump pressure reading is below normal.

- Last-pass draft. This entry indicates the actual draft produced by the stack or the induced-draft fan. Ensure that you are familiar with the last-pass draft at various firing rates when the boiler is operating satisfactorily. A decrease in the last-pass draft with other conditions constant indicates leaking baffles. An increase shows gas passages are becoming clogged.

- Percent CO_2 flue gas. This value is a measure of relative quantities of air supplied with fuel. It is kept at a value that has been established as most satisfactory for the plant, fuel, firing rate, and other related factors. In plants not equipped with CO_2 recording meters, this value is determined with a hand gas analyzer. With experience, the correct amount of air supplied to a furnace can be determined from draft gauges and by observation. In all cases, find values by using a hand gas analyzer.

- Flue gas temperature. This shows the quantity of heat leaving the boiler with flue gases. This heat represents a direct energy loss in fuel. Abnormally high flue gas temperatures at given boiler firing rates are caused by dirty heating surfaces or leakage of baffles. When the heating surface has a coating of soot, heat that cannot escape is discharged to the stack. Leakage of heat through baffles allows gases to take a shorter path than intended and reduces the contact of gauges with the entire heating surface. Excessive fouling of firesides of boilers increases draft loss, while leaking baffles decrease draft loss. Either condition raises the temperature of flue gas above normal.

- Fuel. Always determine the quantity of fuel used, as this represents a major operating cost. Fuel oil quantities are determined by the use of a measuring stick and tables supplied with a given tank. Some tanks are equipped with gauges to show the fuel volume.

- Outside temperature. The load on a heating plant is greatly influenced by outside temperature. Record this temperature for comparison with steam generated and fuel used. These comparative values are useful in finding abnormal fuel consumption and in estimating future requirements.

- Makeup water. Record the quantity of makeup water used to enable the operator to note an abnormal increase before a dangerous condition develops. Return all possible condensate to the boiler plant to save water and chemicals used to treat water.

- Water pressure. Feedwater is most important to safe boiler plant operation. A record of water pressure tells whether water is sufficient.

- Hot-water supply temperature. Record hot-water supply temperature. Insufficiently heated water can cause scaling or deposits in a boiler.

- Water softeners. Where softeners are used, keep a meter record to inform the operator when units must be regenerated. A decrease in the quantity of time used for runs between regeneration indicates either an increase in hardness of incoming water or a deterioration of softening material.

- Total and average. Space is provided for recording the total and average quantities per shift.

- Steam flowmeter. The steam flowmeter integrator reading at the start of a shift, subtracted from the reading at the end of a shift, and multiplied by the meter constant gives the quantity of steam generated. Dividing steam generated by fuel burned (gallons of oil) yields a quantity that shows the economy obtained. If a plant does not have a steam flowmeter, pumps can be calibrated for flow and a record kept of their operating time, or condensate and makeup water can be metered.

- Boiler feed pumps in service. A record of boiler feed pumps in service makes it possible to determine operating hours and to ensure that various pumps are used for equal lengths of service.

- Phosphate, caustic soda, and tannin added. A record of phosphate, caustic soda, and tannin used is valuable in keeping the correct boiler water analysis and in determining total chemicals used.

- Remarks. The remarks column is used to record various types of information for which space is not provided elsewhere on the log sheet. List equipment to be checked daily. Note all irregularities that are found during inspections. List the date when boilers are drained and washed out thoroughly at intervals determined by local water conditions. Show the condition of internal cleanliness.

- Other personnel. Names of personnel responsible for specified tasks and data must be entered on the log sheet, if required.

BOILER OPERATION

The operation of a boiler consists of seven major phases: prewatch assumption checks, preoperating checks, lining up systems, operating procedures, operating checks, securing procedures, and boiler emergencies.

PREWATCH ASSUMPTION CHECKS

The prewatch assumption checks are often neglected by boiler watch standers. Before you assume the responsibility of a boiler watch stander, you must complete specified checking procedures to ensure that the equipment in service is in sound operating condition and is functioning satisfactorily. Normally, when the watch is relieved, the watch stander coming on duty inspects the instrument readings and charts, visually inspects all equipment, and exchanges information with offgoing watch standers. Oncoming watch standers should complete the following inspections and tests before assuming duty:

- Visually inspect setting and casting.

- Observe furnace and firing conditions.

- Inspect charts to determine apparent performance of equipment, controls, and so forth.

- Inspect fans, dampers, damper drives, and other driven auxiliaries.

- Test water columns and gauge glasses.

- Test alarm units.

- Obtain information on the boiler's operating condition and ask the watch standers on duty if any unusual event or trouble occurred during their watch period.

Immediately after accepting the operational responsibility, you should make a complete inspection of all auxiliary equipment as follows:

- Inspect all electric motor drives for evidence of abnormal temperature, condition of bearings, and so on.

- Inspect the fan and pump bearings for evidence of overheating and adequacy of lubrication.

- Visually inspect the boiler and all associated equipment, being careful to listen for unusual sounds, friction, vibration, and other abnorrmal conditions.

- Inspect the burners, fuel supply, pilot systems, and other fuel supply components.

- Review the log sheets to obtain information on past operating conditions and unusual events.

PREOPERATING CHECKS

The preoperating checks should be completed before lining up and lighting off a boiler. These checks are performed to ensure that the plant and associated equipment are in a safe and efficient operable condition. The major preoperating procedures applicable to boilers in general are as follows:

1. Inspect boiler room or area for safety and fire hazards.
   a. Remove rags, paint cans, oil spots on floor, and so on.
   b. Remove tools and equipment from area that may cause injury.
2. Furnace and gas passages.
   a. Must be clean and clear.
   b. All doors must fit tight.
   c. Must be in good repair.
   d. Make sure there is no oil or tools in combustion chamber.
   e. Must be purged.

3. All valves must be inspected for the following:
    a. Good operating condition.
    b. Bent stems.
    c. Missing or broken handwheels.
4. Piping.
    a. Inspect all piping for leaks.
    b. Check for proper supports.
5. Electrical system should be checked for the following:
    a. Oil-soaked or frayed wire insulation.
    b. Damaged or loose conduit.
    c. Improperly secured control boxes.
6. Guards. Make sure that guards for moving parts are tight and in proper position
7. Water-gauge glass.
    a. Must be well lighted.
    b. Must not be stained.
    c. Must not leak at connection.
    d. Should have a guard in place.
8. Dampers.
    a. Must not stick.
    b. Must be in good working order.
    c. Must be open before lighting off.
9. Air cock.
    a. Open to adjust water level on cold boiler.
    b. Open to vent boiler of air, if boiler is cold.
10. Pressure gauge.
    a. Must be correct and clean.
    b. Must be well lighted.
    c. Cock in line must be open.
11. Steam line drains. Open them if the line is cold.
12. Protective controls.
    a. Check low-water cutoff.
    b. Flame failure.
        (1) Test frequently, with burner operating.
        (2) Frequency depends upon base or battalion regulations.
13. Auxiliary equipment.
    a. Ensure that the following major items are in a safe and operable condition and lubricated.
        (1) Boiler feed pumps.
        (2) Oil pumps.
        (3) Draft fans.
        (4) Feed tank.
        (5) Feedwater heater.

Before operating GAS-FIRED BOILERS, you should check the following items in addition to those listed above:

1. The pilot and main gas cock for smooth operation.
2. All copper tubing for restriction because of kinks and flat spots.
3. Air shutters.
    a. Must operate freely.
    b. Linkage must not have too much lost motion.
4. Burner and main gas valve must be firmly supported.
5. Be sure boiler room has no free gas. If gas is present, ventilate the room and test the piping with a soap solution.

Before operating OIL-FIRED BOILERS, you should check the following items:

1. Strainers.
    a. Inspect and clean.
    b. Renew if wire mesh is defective.
2. Burners.
    a. Must be clean.
    b. Nozzle must be clean.
    c. Inspect and set electrodes.
    d. Fittings must not leak.
    e. Check operation of burner safety switch.
3. Oil system. Inspect for leaks, and make necessary repairs.

LINING UP SYSTEMS

After you have completed the preoperating checks, your next job is to line up the boiler systems. The procedures used in lining up boiler systems (fuel, water, steam, and electrical) vary with different types and kinds of boilers. Always follow the manufacturer's instructions for the boiler being used. Before lining up a boiler, complete the following basic tasks:

1. Fuel oil.
    a. Measure with a stick or gauge.
    b. See that the proper valves are open.
    c. Remove any excess accumulation of water in the tank.
2. Gas.
    a. Check pressure.
    b. Check for leaks.

3. Gas-fired unit.
    a. Check and regulate the water level and line up the feed system.
    b. Examine burner, control valves, and safety shutouts for proper working condition before lighting off.
    c. Purge air out of the gas lines by external vents before lighting off.
    d. Check draft devices and purge the combustion chamber.
    e. Light the pilot and set flame.
    f. Open the main gas cock.
    g. Close burner control switches to ignite burner.
    h. Maintain the fuel-air ratio for complete combustion.
4. Oil-fired unit.
    a. Check and regulate the water level. Line up the feedwater system. Check operation of the feed pump.
    b. Line up the fuel oil system.
    c. Purge the combustion chamber.
    d. Close the burner control switch; if automatic, the burner should light off.
    e. Should ignition fail, the furnace must be purged before a second attempt is made.
    f. Do not allow oil to impinge on brickwork or part of boiler.
    g. Maintain the proper air-fuel ratio.

The following basic lighting off procedures are applicable, in general, to most boilers:

1. Close the following valves:
    a. All blowdown valves.
    b. Boiler drains.
    c. Chemical feed valves.
    d. Boiler nonreturn.
    e. Main steam stop.
    f. Soot blower header (steam system).
    g. All burner fuel valves.
    h. All soot blowers.
    i. Water column drains.
    j. Feedwater regulator drains.
    k. Auxiliary valves, as necessary.
2. Open the following valves:
    a. Vent valves on boiler drums and superheaters.
    b. Superheater drain valves.
    c. Recirculating line valves in economizer, if so fitted.
    d. Feedwater stop and check.
    e. Drum steam gauge connection.
    f. Water column gauge connections.
    g. Water column gauge glass valves.
    h. Auxiliary valves, as necessary.

3. Start filling the boiler with properly treated water at a temperature close to the temperature of the pressure parts. The temperature difference should not be greater than 50 °F to avoid severe temperature stresses. Fill the boiler to a level just below the middle of the glass on the water column.

4. Close the induced draft fan dampers (or other flue gas control dampers).

5. Start the induced draft fan.

6. Close the forced draft fan dampers (or other air control dampers).

7. Start the forced draft fan.

8. Start the air heater rotor, if a regenerative type of air heater is installed.

9. Light off the boiler under the manufacturer's instructions and maintain a firing rate so that the water temperature in the boiler is raised 100 °F per hour until operating pressure is reached. On new boilers, expansion movement should be checked to see that no binding or interference occurs.

10. When burning oil, prevent incomplete combustion in the furnace; any unburned oil is deposited on the cooler surfaces in the back of the unit, such as the economizer and air heater. This creates a potentially dangerous situation.

11. When the steam drum reaches about 25 psig, close the vent valves on the boiler drum. Check the steam pressure gauge now to be sure it is registering.

12. Ease up on the stem of the main steam stop valve to prevent any serious expansion stresses. If there is no steam on either side of the main steam stop valve, gently lift and reseat it to make sure that it is not stuck. Open the drain valve on the boiler side of the main stop valve.

13. Observe the water level carefully to ensure that no water is carried over into the superheater. Maintain a normal water level in the drum by blowing down or feeding water as may be required.

14. Operate the vent and drain valves in the superheater headers and economizer by following the manufacturer's instructions. In general, drain valves in the superheater inlet header are closed first, followed by the drains in the superheater outlet header. In any case, the superheater outlet header drain and vent valves

must not be completely closed until enough steam flow through the boiler outlet valve is assured.

15. Check for leaking gasket joints. If a leaking gasket is discovered, shut down the boiler and tighten the joints.

16. If the gasket still leaks, drop the pressure again, replace the gasket and repeat the lighting-off sequence.

Before cutting in the boiler, proceed as follows:

1. Open all drain valves between the boiler and the header, especially the drains between the two stop valves.
2. Warm up the steam line between the boiler and the header by backfeed through the drip line or by means of the bypass valve.
3. When the steam line is thoroughly heated and at header pressure, open the header valve.
4. When the boiler pressure almost reaches line pressure, open the bypass line around the main steam stop valve to equalize pressures and temperatures in the piping; then slowly open the main steam stop valve. As the boiler reaches line pressure and is actually steaming, slowly raise the nonreturn valve stem to the full open position.
5. After the boiler is on the line, close all superheater drains.
6. Inspect the entire boiler, and close any drain valves that are not discharging condensate.
7. Close the economizer recirculating valve when an adequate continuous feedwater flow is established.
8. Close the drain valve at the nonreturn valve.
9. Close the bypass valve around the nonreturn valve.
10. A boiler with a pendant (nondrainable) superheater has a slightly different operation. Superheaters of this type trap condensate in the loops that must be boiled off before the firing rate can be increased and the steam flow started.
11. Maintain a constant firing rate. The strength of thick steam drums may be impaired by excessive temperature differentials between the top and the bottom of the drum, if the proper firing rate is not maintained. Tubes may start leaking at rolled seats and the superheater tubes may overheat.
12. On boilers generating saturated steam, follow the manufacturer's specified firing rate and follow the above instructions for removing air and condensate.

OPERATING PROCEDURES

Success in operating boilers depends largely upon the operator's performance. No fixed set of rules can be established to fit all conditions. Consequently, the operator must see and interpret all prevailing operating conditions and, if necessary, take action to control, modify, or correct them. To be able to do this, the operator must be thoroughly familiar with the characteristics and standard operating procedures for the boiler for which the operator is responsible. This section acquaints you with some of the basic operating procedures that generally apply to most, if not all, boilers you will be assigned to operate. For specific operating instructions, consult the manufacturer's manual for the boiler concerned.

Normal Operation

During normal operation of boilers, the operators have two major responsibilities. The first is to see that proper water level is carried at all times. If the water level is too low, tubes may overheat, blister, and rupture. If the water level is too high, carry-over of water to the superheater tubes may damage the superheater elements and the turbine. Check the water gauge frequently to be certain it is reading correctly and that the proper water level is being maintained. The second major responsibility is to prevent loss of ignition when burning fuel is in suspension, such as gas or oil. Maintain safe and efficient combustion conditions in the furnace and correct fuel-air ratios.

Blowdown

Establish definite intervals for blowing down the boiler, depending on the type of operation and the chemical analysis of the water from the boiler. During regular operation, never blow down economizers or water-cooled furnace walls.

Blowdown valves on this type of equipment serve only as drain valves. Blowdown should be at reduced or moderate rates of steam for low-point drains or blowdown valves. When the water glass is not in full view of the operator blowing down a boiler, another operator should be temporarily assigned to observe the water glass and signal the operator handling the valves. For control of water conditions when working, use a continuous blowdown to maintain the proper concentration at all times and to prevent blowing down large quantities of water while the boiler is operating at a high capacity.

Boiler Makeup Water

Use only properly treated water for makeup, and maintain the boiler water conditions as specified in the water treatment instructions. Make an accurate water analysis at specified intervals. Carefully control the blowdown and the addition of treatment chemicals to meet the manufacturer's specifications.

Soot Removal

Remove soot from hoppers and pits at definitely established intervals, as necessary.

Instrument Readings

Establish definite intervals for observing and recording the readings on all important instruments and controls. Be sure you obtain accurate readings and see that the readings are recorded properly on the log sheet or other required record.

OPERATING CHECKS

To help ensure efficient operation of the boiler, see that the following operating checks are carefully made:

1. Water level.

a. Check frequently as water expands during the heating up period.

2. Main steam stop bypass (if installed).

a. Open if the boiler is to be cut in on a cold line.

b. Main stop can be opened when there is no other boiler on the same steam line.

3. Air cock.

a. Close after steam has formed and has blown all air from the boiler.

4. Steam pressure.

a. Raise slowly—usually 1/2 to 2 1/2 hours, depending upon type, size, and condition of boiler.

b. Temperature of water should be raised at a rate of 100°F per hour.

5. Safety valves.

a. Manually lift when pressure is at least 75 percent of the valve setting.

b. Make sure valves reseat properly; if valves fail to reseat properly, lift them a second time.

6. Cutting the boiler in. If closed, open the main steam stop valve slowly to avoid thermal shock and water hammer.

7. Boiler feedwater. Commence feeding the boiler, as needed. It probably will be automatically controlled.

8. Firing.

a. Gas.
(1) Maintain ignition.
(2) There should be no soot formation.
(3) Maintain proper air-fuel ratio.

b. Oil.
(1) Maintain ignition.
(2) Observe flame and adjust dampers. Check accuracy by flue-gas analysis.

9. Water level.

a. The first duty when taking over the water is to blowdown the gauge glass and water column.

NOTE: Observe the promptness of the return of water in the glass.

b. Keep at proper level.

c. Do not depend entirely upon automatic regulators.

d. At frequent intervals, compare readings of different methods to determine true water level; use try cocks.

10. Boiler blowdown.

a. Rids boilers of mud, scale, rust, and other suspended impurities in the water.

b. Open the quick-opening valve first and the slow-opening valve second. Close in reverse order.

c. Frequency and amount of blowdown depends on water tests.

d. Watch and monitor the gauge glass.

11. Efficient operation.

a. Flue-gas temperature.
(1) Keep temperature low.
(2) Should be about 150 degrees higher than the temperature of the steam being generated.

b. Flue-gas analysis.
(1) Take periodically.
(2) Maintain proper CO_2 level for fuel used.

c. Flame.
(1) Long and lazy.
(2) Must NOT enter the tubes.
(3) Not dark and smoky.
(4) Have a light brown haze from stack, except gas.

best copy available

(5) When the fuel is oil, have yellow flame with dark or almost smoky tips.

d. Draft.
  (1) Usually 0.03-0.06 inch of water.
  (2) Check manufacturer's recommendations.
  (3) Extra draft is needed when stack and refractory are cold.

e. Makeup feed.
  (1) Maintain low rate.
  (2) Repair leaky steam and return lines.
  (3) Avoid excessive boiler blowdown.

f. Insulation.
  (1) Keep boiler and lines well insulated.

g. Feedwater.
  (1) Maintain proper feedwater temperature.

h. Water treatment. Carry out prescribed treatment of boiler water.

SECURING PROCEDURES

The recommended procedures for securing boilers are as follows:

1. Reduce the load on the boiler slowly, cutting out the fuel supply by proper operation of the fuel-burning equipment.

2. Maintain the normal water level.

3. When the boiler load is reduced to about 20 percent of rating, change the combustion control and the feedwater control to manual operation.

4. Before securing the final fuel burner, open the drain valves at the steam and nonreturn valve and the drain valve on the superheater outlet header. Be sure the bypass valve around the nonreturn valve is closed.

5. Secure the final fuel burner when the load has been reduced sufficiently.

6. Continue operating the draft fans until the boiler and the furnace have been completely purged.

7. Shut down the draft fans.

8. Close the dampers, including the air heater and superheater bypass dampers, when provided.

9. Follow the manufacturer's instructions for the rate of cooling the boiler. A thermal strain may occur if the change is too fast.

10. When the boiler pressure has started to drop, close the steam stop and nonreturn valve.

11. When the boiler no longer requires any feed and the nonreturn valve is closed, open the valve in the recirculating connection of the economizer, if provided.

12. Let the boiler pressure drop by relieving steam through the superheater drain valve and the drain valve at the nonreturn valve. If the boiler is losing pressure at a rate faster than specified by the manufacturer, throttle the drain valves as necessary to get the proper rate. Do not close the valves completely.

13. When the drum pressure drops to 25 psig, open the drum vent valves.

14. If a regenerative type of air heater is used, the rotor may be stopped when the boiler exit gas temperature is reduced to 200°F.

15. The boiler can be emptied when the temperature of the water in the boiler is below 200°F. Before sending someone into any part of the boiler, close and properly tag all controls, valves, and drains or blowdown valves connected with similar parts of other units under pressure at the time. This move prevents any steam or hot water from entering the unit. The tags are to be removed only by an authorized person and must remain in place until all personnel have completed their work. Ventilate the boiler thoroughly and station a person outside. Inside, use only low-voltage portable lamps provided with suitable insulation and guards. Even 110 volts can kill under the conduction conditions inside a boiler. All portable electrical equipment should be grounded; and electric extension cords should be well insulated, designed to withstand rough usage, and maintained in good condition.

BOILER EMERGENCIES

Typical emergency situations encountered with the operation of boilers are (1) low water, (2) high water, (3) serious tube failure making it impossible to maintain water level, (4) flareback caused by an explosion within the combustion chamber, (5) minor tube failure indicated by trouble in maintaining water level under normal steam demand, and (6) broken gauge glass on the water column. Table 8-1 lists the safe procedures to follow when these boiler emergencies occur.

CLEANING BOILER FIRESIDES

Boiler heat transfer surfaces must be kept clean to provide for safe and excellent boiler operation. Excessive fireside deposits of soot,

Table 8-1.—Boiler Emergencies

TASKS	KEY POINTS
EMERGENCY ONE: LOW WATER CONDITION INDICATED BY NO WATER LEVEL IN THE GAUGE GLASS. Secure the boiler, secure electrical switches, steam stop and feed stop. Prove water level by opening try cocks. Cool the boiler slowly until the water temperature is 200 °F. Secure all sources of draft. Check controls. Find out the cause for low water level. Correct the trouble. After correction has been made, add water to obtain the correct water level.	DO NOT ADD WATER TO THE BOILER to raise water level in the gauge glass column. STAY AWAY from discharge. DON'T FORCE COOL.
EMERGENCY TWO: HIGH WATER CONDITION INDICATED BY GAUGE GLASS FULL OF WATER. Prove water level by opening the try cocks. Blowdown boiler by opening blowdown valves. Find out the cause of high water condition. Check feed pump controls. Correct the trouble. Secure the boiler if pump controls oeprate improperly.	STAY AWAY from discharge. Check blowdown pit. Watch the gauge glass until normal level is reached. If control operates properly, continue to operate the boiler.
EMERGENCY THREE: SERIOUS TUBE FAILURE MAKING IT IMPOSSIBLE TO MAINTAIN WATER LEVEL. Secure the boiler by securing the electrical steam, and fired systems. Add water to the boiler until the ruptured tube level is reached and the boiler is cooled to a temperature of 200 °F. Open the boiler to replace the tube.	For large boilers: Water should be fed to boiler until properly cooled. Mark the gauge glass if within its range. Observe level by whatever means available.
EMERGENCY FOUR: FLAREBACK CAUSED BY AN EXPLOSION WITHIN THE COMBUSTION CHAMBER. Secure the boiler. Find out the cause of flareback and correct the trouble. Check for sufficient fuel and any type of fuel contamination. Check the burner.	Ensure that a slug of water did not interrupt flame with a refire before prepurge.
EMERGENCY FIVE: MINOR TUBE FAILURE INDICATED BY TROUBLE MAINTAINING WATER LEVEL UNDER NORMAL STEAM DEMAND. Secure the boiler if it is possible to remove it from the line for sufficient time to make necessary repairs. Secure electric switches. Open steam stop and feed stop if additional water is not needed to protect remaining tubes.	If unable to secure the boiler because of steaming requirements, and you can maintain the water level, continue to operate. If unable to maintain the water level and/or supply, secure the boiler.
EMERGENCY SIX: BROKEN GAUGE GLASS ON WATER COLUMN. Secure top and bottom valves immediately. Use chains or whatever method available to prevent injury to personnel. Replace the gauge glass.	Boiler may be kept on the line, if necessary. Check the boiler water level by using try cocks.

scale, and slag cause the following conditions: reduced boiler efficiency, corrosion failure of tubes and parts, reduced heat transfer rates and boiler capacity, blocking of gas passages with high draft loss and excessive fan power consumption, and fire hazards.

Methods for cleaning boiler firesides and preventing excessive deposits of soot, slag, and scale include wire brush and scraper cleaning, hot-water washing, wet-steam lancing, and sweating.

WIRE BRUSH AND SCRAPER CLEANING

When too much soot is deposited and the passages become plugged, hand lancing, scraping, and brushing are generally used. Special tools required for reaching between the lanes of tubes may be made from flat bars, sheet metal strips cut with a saw-toothed edge, rods, and similar equipment. Some boilers have different sizes of tubes, so you need various sizes of brushes and scrapers to clean the boiler tubes. The brushes or scrapers are fastened to a long handle, usually a piece of pipe, inserted and pushed through the tubes.

HOT-WATER WASHING

This method of cleaning boiler firesides is often used to clean superheaters, economizers, and other sections of the steam generator that are difficult or impossible to reach by brushing or scraping. The water may be applied with hand lances and/or boiler soot blowers. Dry out the boiler setting immediately after water washing to reduce damage to the refractory and other parts of the setting. Observe the following safety precautions when washing boiler firesides:

- Wet the boiler refractory and insulation as little as possible.
- Be sure that sufficient fresh water is available to complete the washing.
- Protect electrical equipment around or under the boiler from water damage.
- Install canvas shields or gutters where possible to reduce wetting of refractories.
- Provide all necessary instructions, gloves, goggles, protective clothing, and other equipment to prevent workers from being scalded.
- Provide a compressed air lance to loosen scale after water washing.
- Provide adequate equipment to heat and pump the hot water. The water should be heated to about 150°F. Water exceeding this temperature cannot be handled safely and efficiently; cold water does not clean satisfactorily. A water pressure of 200 to 250 psig should be provided at the cleaning lances or soot blowers. The water jets must penetrate the tube banks and strike with enough force to break up the slag accumulations.
- Start the water washing at the top of the unit and work down.
- The unit must be dried out immediately after washing.

WET-STEAM LANCING

This method is similar to the hot-water method except that wet steam is used instead of hot water. The steam should be wet and at a pressure of 70 to 150 psig. The unit must be dried out immediately after lancing.

SWEATING

Fireside slag can be removed from the convection superheaters by forming a sweat on the outside of the tubes. Cold water is circulated through the tubes, and moisture from the air condenses on the tubes to produce sweat. The hard slag is changed into mud by the sweat, and the mud can be blown off by an air or a steam lance. A large tank filled with water and ice can be used as the cold-water source. Steam can be blown into the area around the tubes during the cold-water circulating period to provide adequate moisture in the air.

CLEANING PROCEDURES

The procedure for cleaning boiler firesides is as follows:

1. Remove the boiler from service and allow it to cool. Make sure the boiler is cool enough for a person to enter. Someone must be standing by

whenever a person is in the boiler. Do NOT force-cool the boiler with draft fans or by adding cold water.

2. Disconnect fuel line openings. Secure all valves, and chain, lock, and tag all fuel lines to the burner and install pipe caps.

3. Disconnect electrical wiring. Secure and tag the electrical power to the boiler to the main panel. Remove all fuses from the main electrical panel if practical. Disconnect the burner conduit and wiring. Mark and tag all electrical wires to ensure proper installation when rewiring and connecting the burner for operation. Tape the loose ends of all wires to prevent electric shock.

4. Open the boiler access doors by loosening all nuts and dogs and swing the door open. Use a wrench of proper size and be careful not to damage the refractory door lining.

5. Remove the burner from the boiler openings. Follow the manufacturer's instructions for specified burners. Move the burner out of the work area, and cover it with canvas or rags to prevent damage and contamination. Protect electric equipment, controls, gauges, and other fittings. Wrap this equipment with plastic, rags, or other suitable protective coverings. Remember, soot and loose carbon particles must be kept out of the burner's moving parts at any cost because they can cause the burner to malfunction.

6. Provide all spaces with free air circulation by opening doors and windows, or provide fresh air by mechanical means. Make sure you can breathe easily and comfortably. An assistant should be stationed outside the opening and be ready at all times to lend a hand at tending lines and tools, or being of service in case of mishap. Clean lenses as required. Remove all materials and equipment that interfere with work or create dangerous obstacles. Be sure all electrically powered equipment is grounded to prevent an accident.

7. Cover the floor area around tube ends with drop cloths to catch soot. Position a vacuum cleaner hose at the tube being cleaned to ensure ease of soot removal. Be careful of brushes coming through tube ends. Keep soot from contacting wet areas because soot and water form carbonic acid.

8. Remove tube baffles where possible and pass a hand lance or rotating power cleaner brush through each tube slowly and carefully so no damage occurs to personnel or equipment. Remember, the brush must pass all the way through the tube without stopping to prevent binding. Keep the flexible drive straight and wear suitable gloves for protection from the revolving brushes.

9. Inspect tube surfaces for satisfactory condition before continuing to the next tube. Use a drop cord or flashlight for viewing through the entire length of a tube. Wire brush all tube baffles either by hand or by use of power tools. Remove baffles when possible, or clean in place with a wire brush.

10. Apply a light coat of mineral oil to all cleaned surfaces. To do this, fix an oil-soaked rag to the end of a brush or rod long enough to extend through the tubes and thoroughly swab each surface, including baffles. Mineral oil is the only lubricant that prevents rusting and also burns off freely without leaving a carbon deposit.

11. Clean all flat surfaces by brushing with the hand or power tools. Make sure that powered equipment is grounded.

12. Use an industrial vacuum cleaner to remove loose soot.

CLEANING BOILER WATERSIDES

Any waterside deposit interferes with heat transfer and thus causes overheating of the boiler metal. Where a waterside deposit exists, the metal tube cannot transfer the heat as rapidly as it receives it. What happens? The metal becomes overheated so that it becomes plastic and blows out, under boiler pressure, into a bubble or blister.

The term *waterside deposits* includes sludge, oil, scale, corrosion deposits, and high-temperature oxide. Except for oil, these deposits are not usually soluble enough to be removed by washing or boiling out the boiler.

The term *waterside corrosion* is used to include both localized pitting and general corrosion. Most, if not all, waterside corrosion is probably electrochemical. There are always some slight variations (both chemical and physical) in the surface of boiler metal. These small chemical and physical variations in the metal surface cause slight differences in the electric potential between one area of a tube and another area. Some areas are ANODES (positive terminals).

Iron from the boiler tube tends to go into solution more rapidly in the anode areas than at other points on the boiler tube. This electrolytic action cannot be completely prevented in any boiler. However, it can be reduced by maintaining the boiler water at the proper alkalinity and by keeping the dissolved oxygen content of the boiler water as low as possible.

The watersides of naval boilers may be cleaned in two ways: mechanically, by thorough wire brushing of all drums, headers, and tubes; and chemically, by circulating chemical cleaning solutions through the boiler.

MECHANICAL CLEANING

Before mechanical cleaning of watersides is begun, the internal fittings must be removed from the steam drum. The fittings (particularly the steam separators and apron plates) must be marked or otherwise identified as to position in the steam drum to ensure their correct reinstallation. All internal fittings must be wire brushed and cleaned before they are reinstalled.

Cleaning the watersides of the generating tubes requires a special tube cleaner. There are several types available, but perhaps one of the most common is the pneumatic turbine-driven tube cleaner shown in figure 8-26. This type of cleaner consists of a flexible hose, an air-driven motor, a flexible brush holder, and an expanding wire bristle brush. The turbine-driven motor consists of a set of turbine blades made to revolve when compressed air is admitted through the hose. The turbine-driven motor, in turn, drives the wire brush. There are several sizes of brushes available. (See figs. 8-27 and 8-28.) Figure 8-29 shows a brush refill for the type of brush illustrated in figure 8-27.

Before you start cleaning tubes, be sure that adequate ventilation and lighting have been arranged. Someone should also be stationed outside the drum whose only duty is to act as tender and to assist whoever is working in the drum. In addition, ensure that all needed tools are available and in good condition. Keep a written checkoff list of all tools and equipment taken into the watersides and be sure that the same tools and equipment are removed. There have been many tube failures immediately after a cleaning job from tools or rags left in the boiler.

With the air shut off, insert the tube cleaner in the tube until the brush is about even with the far end of the tube. Wrap friction tape, a rag, or some other marking material around the hose to show how far the tube cleaner can be inserted without having the brush protrude beyond the far end of the tube. Then remove the cleaner from the tube. Remember that the tubes in each row are the same length, but that the tube lengths vary from row to row. Therefore, separate markings have to be made on the hose for each row of tubes.

After the hose has been marked, insert the brush in the tube and turn on the air to start the brush rotating. Pass the brush SLOWLY along the length of the tube until the identifying mark has been reached. Then slowly draw the brush back, withdrawing the cleaner from the tube. Do the same with the rest of the tubes in the row. You don't have to shut off air to the tube cleaner each time the cleaner is withdrawn from the tube.

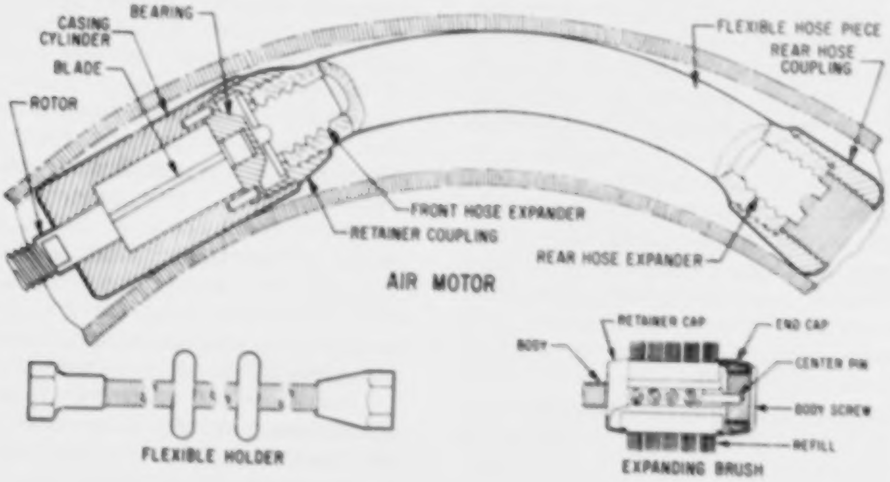


Figure 8-26.—Boiler tube cleaner (pneumatic turbine-driven type).

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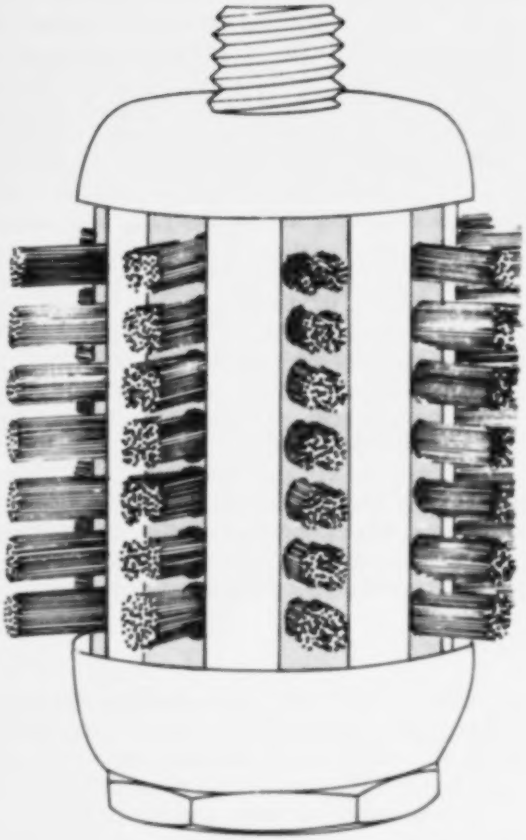

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Figure 8-27.—Wire bristle brush for cleaning generating tubes.

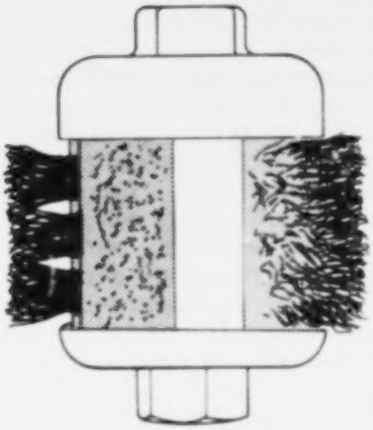

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Figure 8-28.—Wire bristle brush for cleaning large tubes.

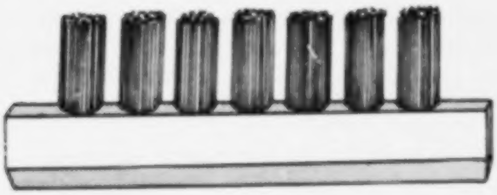

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Figure 8-29.—Brush refill.

However, be sure to steady the brush assembly with your hand to keep the cleaner from whipping. Allowing the brush to whip at either end of the tube is the most common cause of broken tubes.

Establish a new mark for the next row and proceed with the cleaning. Make as many passes as necessary through each tube to ensure adequate cleaning. Be careful not to stop the tube cleaner in any one place in the tube, as the continued rotation of the brush in one place might damage the tube. Be careful, also, to see that the brush and the flexible shaft do not protrude from the other end of the tube, as this may result in a broken shaft.

The tube is most easily cleaned from the steam drum. However, some rows of tubes are not accessible from the steam drum and must be cleaned from the water drum or header. The lower ends of ALL tubes must be cleaned from the water drum or header. You may also find tubes bent so that brushes cannot be forced around the bend without breaking the tube cleaner. These tubes must be cleaned from both ends.

Tube cleaners must be kept in good operating condition. The rotor and blades of the air motor should be kept clean and well lubricated. The hose connections should be kept tight and free from leaks. The flexible shafts should be inspected frequently and renewed when they show signs of wear or damage. When the brushes become too worn to work efficiently, the body of the brush should be retained and a new set of brush refills inserted. When replacing parts on tube cleaners, use only the tools provided for this purpose and be careful not to exert unnecessary pressure. Store tube cleaners in a clean, dry container. Wrap the turbine rotor and casing in a slightly oily rag to prevent rusting.

After all tubes, drums, and headers have been cleaned and after all tools and equipment have been removed from the watersides, blow through the tubes with air; then wash out the drums, tubes, and headers with fresh water. Be particularly careful to remove all dirt from handhole seats. Then examine the seats for scars, pits, or other defects that might cause leakage. All bottom blow, header blow, and test cock valves should be inspected and repaired under the manufacturer's instructions during each waterside cleaning.

After washing, thoroughly dry out the boiler watersides. Inspect the watersides to determine the condition of the metal to see if the cleaning was satisfactory. Also, inspect the boiler to be sure that all parts are tight. Be sure that all openings between drums and gauge glasses, blow valves, and safety valves are clean and free of foreign matter. These openings are sometimes overlooked.

CHEMICAL CLEANING

In most cases, mechanical cleaning is the preferred method for cleaning watersides. Chemical (acid) cleaning requires special authorization, since it requires elaborate and costly equipment and rather extensive safety precautions. However, you may have to use the chemical method, so a limited discussion on it is given here.

Inhibited acid cleaning is used to remove mill scale from the watersides of new or recently serviced boilers. Acid cleaning of boilers has the following advantages when compared with mechanical cleaning: less outage time required; less dismantling of the unit; lower cost and labor; acid reaches areas inaccessible to mechanical cleaners to do a more thorough job; and because the cleaning is more complete, it is possible to examine the unit thoroughly for defects, such as cracks and corrosion pitting.

Acids for Cleaning Boilers

The following acids are used to clean boilers: hydrocholoric acid, phosphoric acid, sulfamic acid, citric acid, and sulfuric acid.

The chemical most frequently used for boiler cleaning is HYDROCHLORIC ACID. It has a relatively low cost and satisfactory inhibitors are available. The chemical reactions with the boiler deposits usually result in soluble chlorides.

PHOSPHORIC ACID can remove mill scale from new boilers. With this acid, the boiler can be fired directly without producing noxious or corrosive fumes. Direct firing produces good circulation and distribution of the cleaning solution. Another advantage of phosphoric acid cleaning is that the metal surfaces resist corrosion after cleaning. When cleaned with phosphoric acid, you must protect metal surfaces from surface corrosion during draining and before neutralization.

SULFAMIC ACID is available in powder that must be placed in solution. The powdered acid is easier and safer to handle than liquid acids in carbons. It does not produce noxious fumes as it dissolves and it is less corrosive than hydrocholoric acid, especially at higher concentrations and temperatures.

CITRIC ACID and SULFURIC ACID are used for removing boiler waterside deposits. Sulfuric acid is economical and easily inhibited. However, a danger is that the sulfuric acid can form insoluble salts, such as calcium sulfate.

Inhibitors

Without inhibitors, acid solutions attack the boiler metal as readily as they attack the deposits. With the addition of suitable inhibitors, the reaction with the boiler metal is greatly reduced. Inhibitors used include arsenic compounds, barium salts, starch, quinolin, and pyridin. Commercial inhibitors are sold under trade names by various chemical concerns. Other inhibitors are manufactured by companies that furnish complete acid cleaning services.

Safety Precautions

Observe the following safety precautions when you are acid cleaning a boiler installation:

- Before acid cleaning, replace all brass or bronze parts temporarily with steel or steel alloy parts.

- Provide adequate venting for the safe release of acid vapors.

- Close all valves connecting the boiler with other piping or equipment.

- Provide competent chemical supervision for the cleaning process.

- Do not exceed the specified acid and inhibitor allowable temperature. The inhibiting effect decreases with temperature rise and the probability of acid attack of the boiler metal increases.

- After acid cleaning, be sure to thoroughly flush out all of the tubes that are horizontal or slightly sloping. Obstructions in these tubes can cause poor circulation, overheating, and failure of tubes when the unit is placed in service.

- Use goggles, rubber gloves, and rubber aprons when handling acids.

- Slowly pour the acid into water when mixing the solutions.

CAUTION: NEVER POUR WATER INTO ACID.

- Do not chemically clean boilers with riveted joints.

- During acid cleaning, hydrogen gas can develop through the reaction of the acid on the boiler metal. Some of the generated gas becomes part of the atmosphere inside the boiler, and the remainder is absorbed by the boiler metal, then liberated gradually. Because hydrogen air mixtures are potentially explosive, be careful when opening a unit for inspection after acid cleaning. Until the atmosphere within the boiler pressure parts has been definitely cleared of explosive gases, do NOT use open flames, flashlights, lighting equipment, or anything that might produce a spark near the openings to the pressure parts. Do NOT enter the boiler. The unit can be cleared of explosive gases by thoroughly flushing the unit with warm water with a positive overflow from the highest vent openings. The water temperature should be as near to 212°F as possible to accelerate the liberation of hydrogen absorbed in the metal. After opening the unit, place air blowers at the open drum manholes to circulate air through the unit. Use a reliable combustible gas indicator to test the boiler atmosphere for explosive mixtures.

Acid Cleaning Procedures

Boiler units can be acid cleaned by either the "circulation" or "fill and soak" method. The circulation method (fig. 8-30) can be used to clean

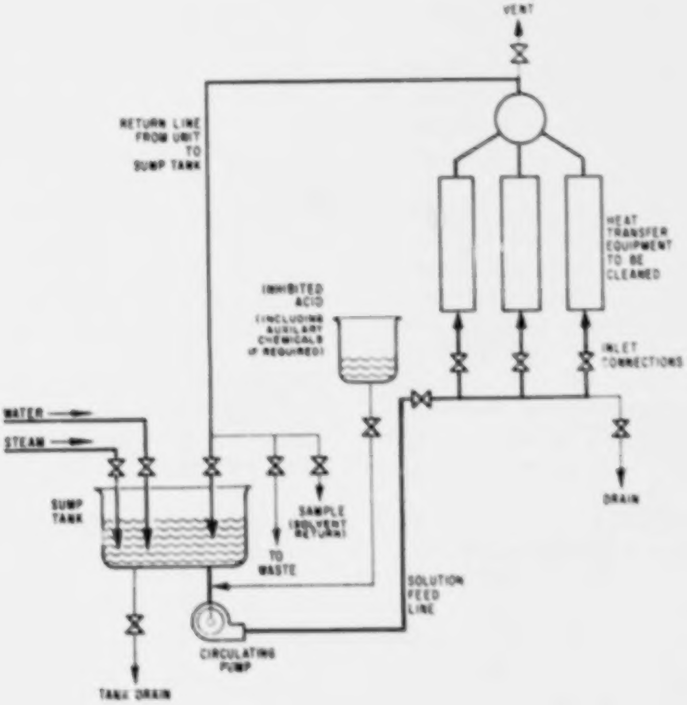
VENT
RETURN LINE FROM UNIT TO SUMP TANK
HEAT TRANSFER EQUIPMENT TO BE CLEANED
INHIBITED ACID (INCLUDING AUXILARY CHEMICALS IF REQUIRED)
INLET CONNECTIONS
WATER
STEAM
SUMP TANK
SAMPLE (SOLVENT RETURN)
TO WASTE
DRAIN
SOLUTION FEED LINE
CIRCULATING PUMP
TANK DRAIN

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Figure 8-30.—Acid cleaning by circulation method.

units with positive liquid flow paths, such as forced circulation boilers. The inhibited acid solution is circulated through the unit at the correct temperature until test analyses of samples from the return line indicate that the acid strength has reached a balance and no further reaction with the deposits is taking place. Because the strength of the acid solution can be determined frequently during the cleaning process, this method can be more accurately controlled and can use lower strength solutions than the fill and soak method.

The fill and soak method (fig. 8-31) is used for cleaning units with natural circulation. The boiler unit is filled with the inhibited acid solution at the correct temperature and allowed to soak for the estimated time. It is not possible to obtain accurate representative samples of the cleaning solution during the soaking period.

Flushing and Neutralizing

After acid cleaning, drain and then flush the unit with clean, warm water until the flushing water effluent is free of acid and soluble iron salts.

Next, a neutralizing solution is circulated through the unit until the effluent shows a definite alkaline reaction. Neutralizing solutions may be of soda ash, trisodium phosphate, sodium tripolyphosphate, or other nontoxic chemicals.

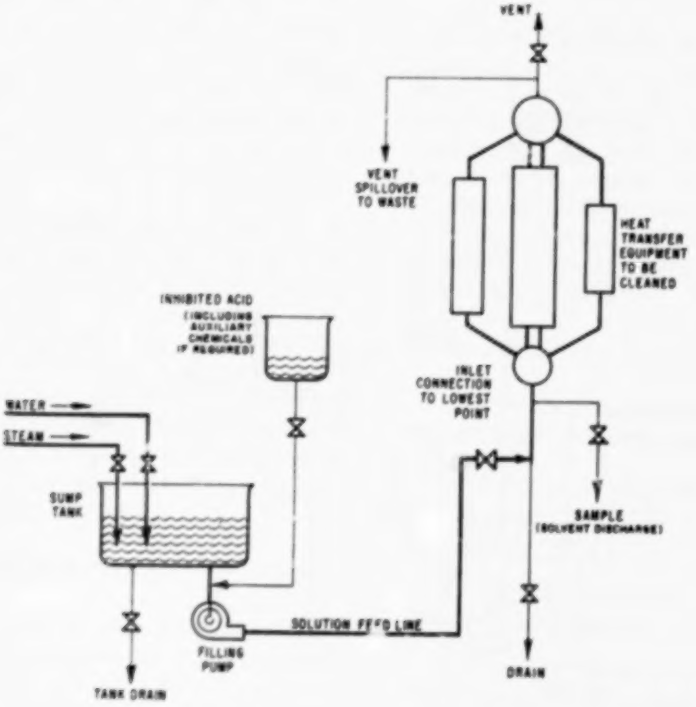
After circulation of the neutralizing solution, the water level can be dropped to the normal level and the boiler fired at 50 psig with open vents to permit the escape of liberated gases.

Finally, the boiler is again drained and flushed with clean, warm water.

BOILING OUT

New boilers, or boilers that have been fouled with grease or scale, should be boiled out with a solution of boiler compound. New boilers must be washed out thoroughly. One method of boiling out is explained below.

Dissolve 5 pounds of caustic soda and 1 1/2 pounds of sodium nitrate, or 10 pounds of trisodium phosphate, for each 1,000 gallons of water the boiler holds at steaming level. Put the


VENT
VENT SPILLOVER TO WASTE
HEAT TRANSFER EQUIPMENT TO BE CLEANED
INHIBITED ACID (INCLUDING AUXILIARY CHEMICALS IF REQUIRED)
INLET CONNECTION TO LOWEST POINT
WATER
STEAM
SUMP TANK
SAMPLE (SOLVENT DISCHARGE)
SOLUTION FEED LINE
FILLING PUMP
TANK DRAIN
DRAIN

54.413

Figure 8-31.—Acid cleaning by fill and soak method.

mixture into the boiler as a solution. In multiple-drum boilers, divide the charge and put equal amounts in each of the lower drums.

Fill the boiler with hot feedwater to the level of the bottom of the steam drum. Turn steam into the boiler through the usual boiling out connections, or bottom blow, and allow the boiler to fill gradually to the top of the gauge glass.

Steam pressure in the boiler should be kept between 5 and 10 pounds. The boiling out should continue for 48 hours. Immediately after boiling out, give a series of bottom blows to remove the bulk of the sludge. The boiler should be cooled, washed out immediately, and given the usual mechanical cleaning.

You may not always use the above method for boiling out. Another satisfactory method is described below.

Clean out all loose scale, and any scale adhering to the boiler that can be removed manually. Place about 15 pounds of caustic soda or soda ash and 10 pounds of metaphosphate for each 100-boiler horsepower (hp) of the boiler. Then seal the boiler openings but OPEN ALL VENTS. Fill the boiler about three-quarters full with water.

Start the burner and raise the temperature of the water in the boiler to about 200°F. Maintain this temperature for 24 to 48 hours. Add makeup water as required during this period to fill the boiler to the base of the safety valve.

Analyze the boiler water during the boiling out period and add enough caustic soda and metaphosphate to maintain the following concentrations:

Causticity as ppm OH 300 to 500
Phosphate as ppm PO_4 100 to 150

Open the boiler at the end of the boiling-out period and clean out the sludge and loose scale. Pay particular attention to removing scale and sludge from water legs in fire-tube boilers. Flush the boiler thoroughly.

If a lot of corrosion is exposed when the scale is removed, notify your superior so a boiler inspection can be made.

When the boiler is operated, any residual scale may cause faulty operation. The boiler should be taken out of service at frequent intervals to remove sludges formed from disintegrated scale. As soon as personnel can work in the boilers, wire brush the drums and ends of all tubes. Then clean the interior of all tubes, using the approved style of boiler tube cleaning brushes.

You should operate all cleaners in the same way. Start the cleaner rotating and insert it in the tube. Pass it slowly along until it comes out the other end of the tube. Immediately reverse the direction and bring the cleaner back through the tube and withdraw it. DO NOT STOP the cleaner at any point in the tube as it may cut through the tube. Also be careful not to extend the cleaner too far out at the end of the tube.

After cleaning all the tubes, follow up by blowing them out thoroughly with a strong air jet. Then inspect to see if replacement of any of the tubes is necessary.

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CHAPTER 9

HOT-WATER AND WARM-AIR HEATING SYSTEMS

Learning Objective: Identify the principles and theory of heating and the procedures required for installing, maintaining, troubleshooting, and repairing hot-water and warm-air heating systems and associated peripheral equipment.

Heat is one of the prime necessities of life. It is as essential as food, clothing, and shelter. You can have a very good shelter, but you still need heat to be comfortable in it. By studying this chapter, you will start to gain knowledge of what you will be required to know to become efficient in your career field.

In this chapter, the methods of heating are discussed. However, the first step is to discuss the following information:

- The theory of heat
- The measurement and transfer of heat
- Combustion
- Primary air
- Secondary air
- Perfect combustion
- Determining the volume of carbon dioxide
- Heat loss
- Heat loss scales
- Determining combustion efficiency

Knowledge of the theory of heat, and the measurement and transfer of heat will be useful to you in understanding how heat is produced and how it gets from your heating plant to the space you are going to heat. Knowledge of combustion, primary air, secondary air, perfect combustion, determining the volume of carbon dioxide, heat loss, heat loss scales, and determining combustion efficiency is very important information if you are to properly perform your job as a heating specialist. Also, this knowledge is a must if you intend to operate a heating plant efficiently.

PRINCIPLES OF HEATING

It is not known exactly when fire was discovered, but there is no doubt that fire is one of the greatest gifts to the world. The need to control and apply fire was apparent from the very first. Imagine what living conditions were during the cave-dwelling period. Unless a natural flue or some other method of ventilation existed as a result of the cave, the smoke from fires during cold weather must have created almost unbearable conditions, leaving the inhabitants the choice of either freezing or being asphyxiated.

Long after people had advanced to the stage of housebuilding, heating methods had not improved much. For centuries (and occasionally, even today) fires for heating and lighting were contained in braziers or confined to an unused corner of a room. The smoke was supposed to escape through a hole left in the roof of the building during construction. Of course, a considerable amount of rain and snow entered the room during bad weather. During the twelfth century, however, the people in the northern part of Europe started using crude fireplaces and flues to replace the brazier and hole-in-the-roof method of heating. Some of these rudimentary heating systems still exist in France.

In the thirteenth and fourteenth centuries, the round hollow stone chimneys began to be used. At the end of the fifteenth century, people were using a number of fireplaces in their homes and grouping the chimneys together in a vertical, rectangular mass of masonry with decorative effect. By the end of the Italian renaissance period chimneys were in common use.

During colonial days in America, the fireplace chimneys were a large masonry mass projected through the center of the roof or were an important feature of the gable end walls. This general trend is often followed in architecture today. Central heating, where fires are required 5 or 6 months of the year, makes the chimney an important feature of a heating plant. There are heating installations, however, that do not make use of the masonry chimney and have substituted an inconspicuous metal smoke pipe. Other types of heating, such as electrical heating, require no chimney.

THEORY OF HEAT

Heat is a form of energy that is known for its effect. Heat can be produced or generated by the combustion of fuels, by friction, by chemical action, and by the resistance offered to the flow of electricity in a circuit. However, the particular form of generated heat with which the heating specialist will be dealing is produced by combustion. This is heat obtained by burning common types of fuels, such as coal, oil, and gas.

MEASUREMENT

To efficiently operate a heating plant, you must be familiar with the measurement of heat and how this heat is transferred from the plant to the space being heated. The first part of this section is devoted to measuring temperature; the second part is concerned with the transfer of heat from the plant to the space being heated.

Measurements of temperature and pressure, which are obtained continuously, are very important factors in the operation of a heating plant. The degree of correctness of these measurements directly affects the safety, efficiency, and reliability of the operation of the heating plant. Although heat and temperature have a direct relationship, there is also a distinction between them. For example, a burning match develops a much higher temperature than a steam radiator, but the match does not give off enough heat to warm a room. Another example tells us that 10 pounds of water at 80 °F will melt more ice in a given length of time than 1 pound of water at 100 °F. The former has more heat, but the latter has a higher temperature. Temperature is the measurement of heat intensity in degrees Fahrenheit or Celsius. Therefore, temperature measurements can be made by using a glass thermometer calibrated either in degrees Fahrenheit or Celsius. The generally accepted way of stating measurements of temperature is in degrees Fahrenheit. The Fahrenheit thermometer is the standard used primarily in English-speaking countries.

The thermometer measures the degree of sensible heat of different bodies. The thermometer can make a comparison only between the temperature of a body and some definitely known temperature such as the melting point of ice or the boiling point of water. Figure 9-1 shows a comparison of the scales of Fahrenheit and Celsius thermometers. It also shows the marking of the freezing and boiling points of pure water at sea level. The range of the Fahrenheit thermometer between the freezing point and the

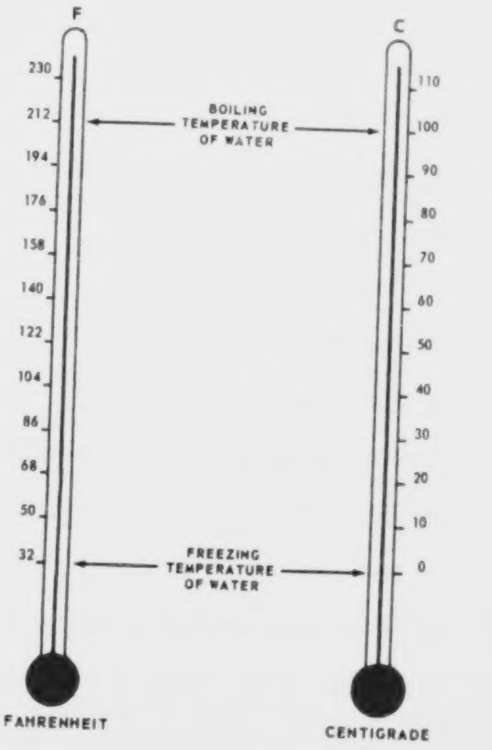

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Figure 9-1.—Comparison of Fahrenheit and Celsius thermometers.

boiling point is 180° (32° to 212° = 180°). On the Celsius thermometer, the range is 100° (0° to 100° = 100°) from the freezing point to the boiling point.

To convert Fahrenheit readings to Celsius readings, subtract 32° from the Fahrenheit temperature reading and multiply the remainder by .556, or $\frac{5}{9}$. To change Celsius readings to Fahrenheit readings, multiple the Celsius temperature reading by 1.8, or $\frac{9}{5}$, and add 32°. The heat that can be measured by a thermometer and sensed or felt is referred to as sensible heat. An example of sensible heat is presented by placing a small vessel of cold water over a gas flame and putting a thermometer in the water. Upon observation, you note that the thermometer indicates a rise in temperature. Also, if you place your finger in the water several times, you will feel (or sense) the change in temperature that has taken place.

The unit of measurement for a given quantity of heat is the British thermal unit, abbreviated and commonly known as Btu. One Btu is the amount of heat needed to change the temperature of 1 pound of pure water 1° Fahrenheit at sea level. If one Btu is added to 1 pound of water at 50 °F, the temperature of that pound of water will be raised to 51 °F.

All substances above absolute zero contain heat. There is heat even in ice, and its melting point is fixed at 32 °F. Because of a fundamental law of nature, when ice at 32 °F melts into water at 32 °F, a change of state takes place. The ice (solid) has turned into water (liquid). A certain amount of heat is required during this change of state. This heat is known as the latent heat of fusion. When 1 pound of ice changes to water, 144 Btu are required, and an additional 180 Btu are required to further raise the temperature of the water to 212 °F, the boiling point at sea level.

To again change the state of this 1 pound of water, (once ice) at 212 °F to steam, another 970 Btu are required. This additional heat is known as the latent heat of vaporization. Latent heat is the amount of heat required to change the state of a substance without a measurable change in temperature. Heat indicates the quantity of units of heat (Btu) in a substance, while temperature indicates the intensity of heat in degrees.

There are other types of heat that you will encounter as a heating specialist. These are specific heat, superheat, and total heat. Specific heat is the ratio between the quantity of heat required to raise the temperature of 1 pound of any substance 1 °F and the amount of heat required to raise the temperature of 1 pound of pure water 1 °F. Superheat is the amount of heat added to a substance above its boiling point. Total heat is sensible heat plus latent heat.

We previously mentioned absolute zero. But, what is absolute zero? Scientists have arbitrarily determined that when the temperature of a substance has been reduced to −460 °F, practically all the heat has been removed from the substance. At this point the molecules cease to have motion. This temperature is known as absolute zero, and it is about the lowest temperature obtainable. Heat is said to be present in all substances when the temperature is above absolute zero.

HEAT TRANSFER

The transfer of heat is the next problem to consider after the heat has been produced by burning of fuel. It must be moved to the space where it is to be used. Heat always flows from a warmer to a cooler substance; consequently, there must be a temperature difference before heat can flow. Naturally, the greater the difference in temperature, the faster the heat flow. Two objects that have different temperatures, when placed together, tend to equalize their temperatures. Heat travels in heating systems from one place to another by three different methods. All three of these methods are used in most heating systems; they are discussed in the paragraphs that follow.

Conduction

Conduction is the flow of heat from one part of a substance to another part of the same substance or from one substance to another when they are in direct contact.

When one end of a stove poker is held in a flame, the other end will soon be too hot to hold. This indicates that the heat is being conducted, or transferred, from one end of the poker to the other end. Such a transfer of heat is called conduction. Conduction is used to transfer heat through the walls of a stove, furnace, or radiator so that the warmth can be used for heating. If a piece of wood had been used instead of the poker, the end of the wood away from the fire would have remained cool. This shows that some materials do not conduct heat as well as others.

Those materials which offer considerable resistance to the flow of heat are referred to as insulators or poor conductors.

Convection

Convection is the transfer of heat by means of mediums such as water, air, and steam. When air is heated, it expands, becomes lighter in weight, and rises. The cooler air, which is heavier, then flows in to replace the warm air. Thus, a convection current is set up. Water, when heated, acts in the same way as air. The water next to the heating surface becomes warmer, lighter, and rises. This action allows the cooler water to flow in next to the heating surface and become heated. Convection is a very important factor in a heating system. It is this force, developed by heating the medium, that circulates that medium to the space to be heated.

Radiation

Radiation is the transfer of heat through space. When a hand is held in front of a stove, it is quickly warmed by means of radiation. In this same manner, the earth receives its heat from the sun.

Radiated heat is transferred by heat waves, similar to radio waves. Heat waves do not warm the air through which they pass, but they must be absorbed by some substance to produce heat. For example, when you stand in the shade of a tree, you feel cool because the leaves and limbs are absorbing the heat waves before they reach you.

When heat waves strike an object, some are reflected, some may pass through, and the rest are absorbed by the object. Polished metals are the best reflectors known; therefore, they are poor absorbers of heat. A poor absorber is also a good radiator. Rough metal absorbs heat more readily than a highly polished metal, and it also loses heat faster by radiation.

The color of a substance also affects its absorbing power. A black surface absorbs heat faster than a white one. That is why light-colored clothes are cooler in summer than dark-colored ones.

COMBUSTIBLE FUELS

If electricity and coal are disregarded, the fuels most commonly used with heating equipment are either gaseous or petroleum. Next, a brief look at the types and characteristics of combustible gases and fuel oils used for heating units is presented.

TYPES OF GASES

Gaseous fuels are usually classified according to their source, which, in turn, determines their chemical composition. The heat value, expressed in Btu per cubic foot, varies with the type of gas and determines the quantity required for a specific heating requirement. The types principally in use are natural gas, manufactured gas, and liquefied petroleum gas (table 9-1).

Natural Gas

Natural gas is a mixture of combustible gases and usually small amounts of inert gases, obtained from geologic formation. While the composition of natural gas varies with the source, methane (CH_4) is always the major constituent. Most natural gases also contain some ethane (C_2H_6) along with small amounts of nitrogen and carbon dioxide. Natural gas is colorless and odorless in its natural form; however, a distinctive odor is usually added as a safety factor for detecting leaks. It mixes readily and completely with combustion air, and thus is substantially free from ash and practically smokeless. These characteristics contribute to good environmental pollution control. From the standpoint of trouble-free performance and ease of handling and control, natural gas offers many advantages that make it the most desirable of all heating fuels.

Manufactured Gas

The common manufactured gases are carbureted water gas, oil gas, and producer gas. These gases are roughly one-half hydrogen and one-third methane, plus small amounts of carbon dioxide, nitrogen, and oxygen. They are made by converting low-grade liquid or solid fuels to the gaseous form by destructive distillation (cracking) of oil or coal, by the steam-carbon reaction, or by a combination of both processes. These gases are ordinarily used at or near the production point because high manufacturing costs rule out the added expense of distribution.

Liquefied Petroleum Gas (LPG)

Liquefied petroleum gases are hydrocarbon gases normally obtained as a byproduct of oil refineries or by stripping natural gas. These compounds are normally gaseous under atmospheric conditions; however, they can be liquefied by moderate pressure at normal temperatures.

The principal LPG products are propane and butane. Propane, the most common, is available by the bottle or cylinder and in bulk form. Its boiling or vaporization point is −44°F; note that this is very close to that of refrigerant R-22.

Butane is generally available in bulk form. It boils or vaporizes at 32°F. In other words, if the temperature of butane is 32°F or lower at atmospheric pressure, it remains a liquid and heat must be applied to bring it to the gaseous state. Like propane, it is stored and transported in the liquid state under pressure and must be vaporized when used as a fuel.

Hazards related to the use of propane and butane include explosion and asphyxiation. Their vapors are heavier than air and settle when released in air; a mixture as low as 2 to 9 percent with air will burn if ignited. A heavy concentration of either of these gases in a poorly ventilated room could cause synthetic intoxication, and finally asphyxiation, depending on the amount of exposure. As a safety factor, manufacturers odorize the gases so that leaks can be quickly detected.

Note in table 9-1 the high heating values of propane and butane.

FUEL OILS

Fuel oils are derived from crude oil, which consists primarily of compounds of hydrogen and carbon (hydrocarbons), and smaller amounts of oxygen, nitrogen, and sulfur, depending on the source. Practically all fuel oil is either a product or a byproduct of refining crude oil by the fractional distillation process or by cracking.

Fuel oil is grouped into four general classes: topped crudes, distillate, residual oils, and refinery wastes. Topped crude oil is the result of a process termed *topping*. Topping takes out gasoline, kerosene, and gas oil, leaving an oil suitable for fuel. Distillate is produced by passing crude oil through complete distillation. The distillate is distilled off between the kerosene and lubricating oil fractions. Residual oils comprise what is left after distilling off most of the lighter parts of the crude oil. They usually contain heavy tars and impurities. The refinery wastes have little or no commercial value and are usually burned as fuel at the refinery.

Commercially used fuel oils are standardized by the Bureau of Standards of the United States Department of Commerce. The oils are numbered

Table 9-1.—Fuel Gases

Fuel	Source	Heating Value Btu per cu ft	Remarks
Natural Gas	Gas wells	700-1300 average 1000	Ideal fuel, piped to point of use
Manufactured Gas			
Carbureted Water Gas	Manufactured from coal enriched with oil vapors	520-540	Good fuel, but usually costly; part of most city gas
Oil Gas	Manufactured from petroleum	520-540	Used on west coast; often mixed with coke oven gas
Producer Gas	Manufactured from coal, coke, wood, etc.	135-165	Requires cleaning
Liquefied Petroleum Gas			
Propane	By-product of gasoline	2500	Boiling point -44° F. Liquefies under slight pressure
Butane	By-product of gasoline making	3200-3260	Boiling point 32° F. Liquefies under slight pressure

in grades 1, 2, 4, 5, and 6 and are titled commercial standard grades (CSG). These grades are identified in the Navy by military specifications and are intended for use in oil burning equipment for the generation of heat in furnaces for heating buildings, for the generation of steam, and for other purposes. A comparison of fuel oils by grade is given in table 9-2.

Viscosity

The ease or difficulty with which an oil flows is its viscosity. It is measured by the time in seconds a standard amount of oil takes to flow through a standard orifice in a device called a viscosimeter. The usual standard is the saybolt universal or the saybolt furol for oils of high viscosity. Tests must be made at a standard temperature, usually 100°F for saybolt universal and 122°F for furol. Viscosity indicates the way oil behaves when pumped; and more particularly, it shows when preheating is required and what temperature must be held.

Specific Gravity

Specific gravity forms a reliable guide to the heating value of fuel oil. This is due mostly to its principal elements, carbon and hydrogen. Hydrogen, for example, has a high heating value and a low atomic weight compared to the other elements. Specific gravity in degrees API (American Petroleum Institute) is found by dividing specific gravity with respect to water at 60°F into 141.5, and subtracting 131.3 from the answer. Gravity in degrees Baume is found in the same way except the numbers are 140 and 130, respectively. The term *Baume*, as applied to fuel oils, is a scale that indicates the weight of oil per unit volume at 60°F.

Flash Point

The flash point of oil is the temperature at which it gives off enough vapor to flash when a jet of flame is passed near its surface. Flash point measures oil volatility and indicates maximum temperature for safe handling.

Table 9-2.—A Comparison of Fuel Oils

Grade Number	Approximate Weight/ Gallon	Heating Value Btu Per Gallon	Type Fuel
1	6.92	136,000	A volatile distillate oil for use in burners which prepare fuel for burning solely by vaporization
2	7.08	138,500	A moderately volatile distillate oil for use in burners which prepare fuel for burning by a combination of vaporization and atomization
4	7.58	145,000	A residual oil for burner installations not equipped with preheaters
5 (Light)	7.83	148,500	A residual oil of intermediate viscosity for use in burners equipped with preheaters; however, preheating may or may not be required depending on climate and equipment
5 (Heavy)	Greater than 5 light	Greater than 5 light	A residual oil of greater viscosity than 5 light. Preheating may be required before burning this oil; and in cold climates preheating may be required before handling as well
6	8.16	152,000	A residual oil of high viscosity for which preheating is always required

Pour Point

The pour point represents the lowest temperature in degrees Fahrenheit at which an oil flows under standard conditions. Its application is more useful to lubricants used for machines exposed to low temperatures and to diesel fuels rather than to fuel oils.

Sedimentation and Water

The amount of water and insoluble solid impurities in fuel oil should not exceed 2 percent. Such incombustible impurities show up as ash and may cause wear of refractories and form slag coatings. The centrifuge method is considered by the American Society of Testing Materials (ASTM) as the most desirable means of determining the content of these materials.

You may refer to *Fundamentals of Petroleum*, NAVPERS 10883 (Series), for more specific information.

Combustion

Combustion is the rapid union of fuel, oxygen, and heat. You will find that to produce and maintain a fire, fuel, air, and heat are necessary. You will also learn that the absence of any one of these ingredients prevents burning or stopping the fire. It is usually easy to understand that fuel is needed for burning, but it is sometimes difficult to understand that air and heat are also required.

To better understand the need of air for combustion, just recall that a burning match stops burning soon after it is dropped into a bottle. This is because all the oxygen in the bottle is quickly consumed by the flame.

Remember, heat is also needed for combustion. This is because the temperature of the fuel has to be raised to its flash point before it starts to burn. The flash point of a substance is the temperature to which the substance must be heated for it to ignite. Every combustible substance has its own definite flash point (ignition temperature). Substances such as paper and oil require only a small amount of heat before they ignite. Others require a considerable amount of heat. When this temperature is reached, the substance begins to combine rapidly with oxygen in the air and soon creates a flame or fire which gives off heat. Light may also be given off.

Too much fuel or not enough oxygen or heat produces incomplete combustion. The three ingredients (fuel, air, and heat) must be present in the correct amounts to provide complete combustion. When combustion takes place, the principal result is heat. Other byproducts such as carbon monoxide, carbon dioxide gases, and water vapor are also obtained.

Controlling combustion after a fire is built is an immediate problem. Air, fuel, and heat are necessary for combustion, and changing the amount of one or more of these can cause the fire to burn faster or slower. Two methods of controlling combustion are widely used. One method is to furnish a constant amount of air to the fire and vary the quantity of fuel. The other method is to furnish a constant quantity of fuel and vary the amount of air.

UNIT HEATERS

In this manual the term *unit heater* is defined as an installed equipment item and a component of a system consisting of an extended or finned heat transfer surface (coil), and a propeller or blower fan to create airflow through it. Unit heaters are indirect units that differ from space heaters because they generate heat indirectly from a medium of steam or hot water piped through a central distribution system. Space heaters are direct-fired units that generate heat directly by the use of an electrical coil or by a combustible fuel.

Unit heaters can be used for many heating requirements, the major limiting factor being the availability of a steam or hot-water system. They are commonly used with heating systems in shops, offices, dining halls, and warehouses. There are three basic types: the suspended horizontal discharge, the vertical or down discharge suspended from the ceiling, and the floor-mounted or horizontal typ of blower unit. Two types of unit heaters are shown in figure 9-2.

The units are rated in Btu or equivalent direct radiation heat output and cubic feet per minute air discharge capacity at a given fan or motor speed. These ratings are important in the application of unit heaters. Manufacturers furnish information regarding the area effectively heated by units to enable proper planning and location of the units. Generally, units under 50,000 Btu per hour are designed to operate on low-pressure steam or high-temperature hot water.

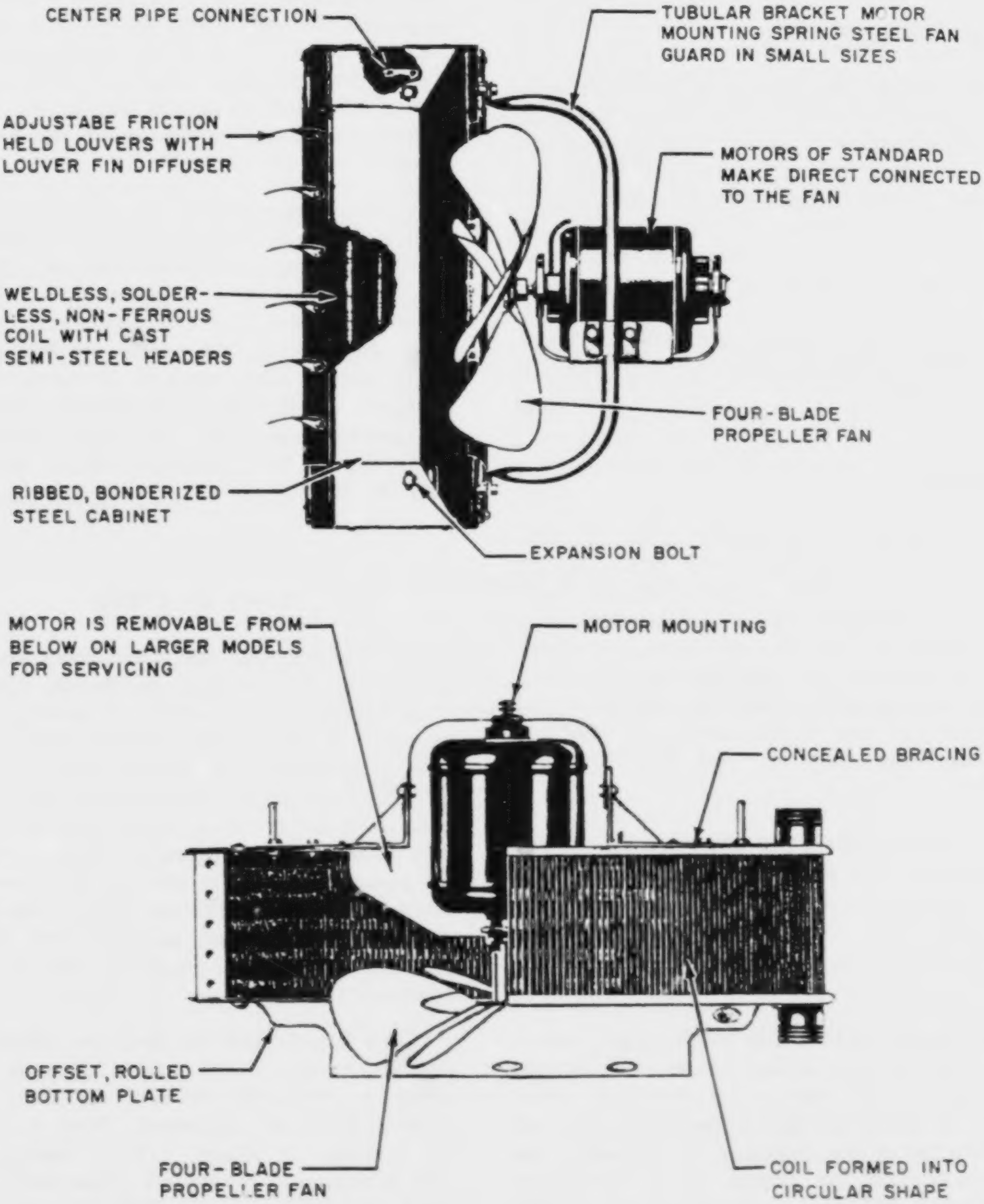
CENTER PIPE CONNECTION
TUBULAR BRACKET MOTOR MOUNTING SPRING STEEL FAN GUARD IN SMALL SIZES
ADJUSTABE FRICTION HELD LOUVERS WITH LOUVER FIN DIFFUSER
MOTORS OF STANDARD MAKE DIRECT CONNECTED TO THE FAN
WELDLESS, SOLDER-LESS, NON-FERROUS COIL WITH CAST SEMI-STEEL HEADERS
FOUR-BLADE PROPELLER FAN
RIBBED, BONDERIZED STEEL CABINET
EXPANSION BOLT
MOTOR IS REMOVABLE FROM BELOW ON LARGER MODELS FOR SERVICING
MOTOR MOUNTING
CONCEALED BRACING
OFFSET, ROLLED BOTTOM PLATE
FOUR-BLADE PROPELLER FAN
COIL FORMED INTO CIRCULAR SHAPE

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Figure 9-2.– Unit heaters.

SPACE HEATERS

Space heaters are used for heating rooms and similarly enclosed spaces, either in addition to, or in place of, a central heating system. They are desirable as a means of providing heat to small spaces because of their simplicity of construction, low initial cost, and reasonable fuel consumption. They may be floated directly in the space or at such a location where heat can be delivered through a single register into the space.

These heaters are sometimes classified by the manner in which they transfer heat to the space to be heated; for example, by radiation and/or convection. The terms *direct-fired* and *indirect fired* are also used to identify such heaters. In this manual, space heaters are identified as direct-fired units and by their heat source or fuel. This discussion will include electric, gas-, coal-, and oil-fired units.

ELECTRIC HEATERS AND INSTALLATION

Space heaters with electrically powered heating elements are used in spaces where it is desired to eliminate cold spots and maintain uniform temperatures, where other fuels are useful as portable units on the floor to overcome floor drafts, and as fixed units mounted in, or to, walls or ceilings. They are generally rated in kW; 1 kW or 1000 watts is equal to 3415 Btu per hour.

Electric space heaters are available in two general types: the radiant and natural convection type and the forced warm air (fan) type. In the first type, heat from electric elements rises and strikes parabolic (bowl-shaped) reflectors. The reflectors are highly polished curved metal surfaces, which deflect the heat outward into the place where heat is desired. (See fig. 9-3.) Some radiant heat units have no deflectors but provide a combination of radiant and natural convection heat, which rises from coils into a chamber open on the side where heat is required. The electric baseboard convection heater is an example of this type. The forced warm-air type uses a motorized fan to circulate heat from the heating element outward into the space (fig. 9-4). These electric units are operated manually with an ON-OFF switch or automatically with a thermostat.

In the selection and installation of electrical space heaters, safety must be assured. Units that are to be installed should bear the label of the Underwriters' Laboratories. They should also conform to the safety standards outlined in space

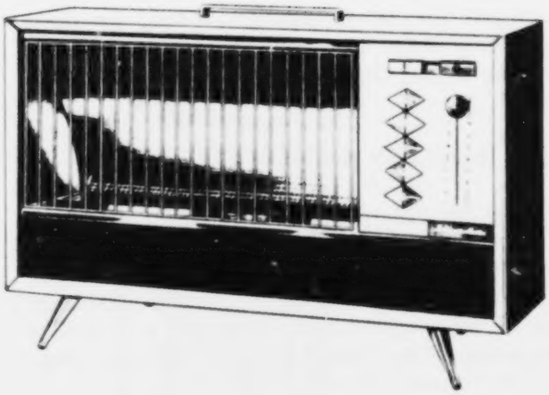

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Figure 9-3.—Radiant electric space heater.

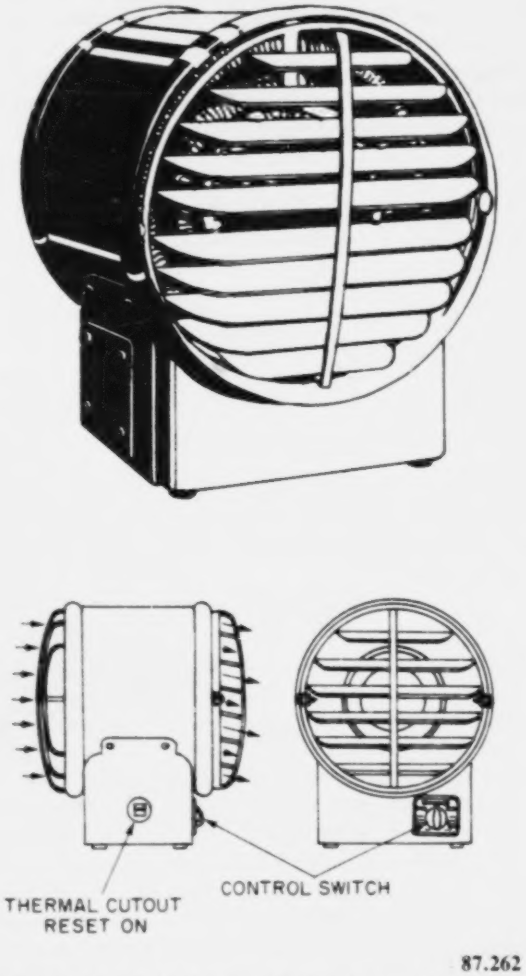

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Figure 9-4.—Forced warm-air electric space heater.

heating equipment UL-573. All electrical work required for an installation should be done according to the manufacturer's instructions and by a qualified electrician.

GAS HEATERS AND INSTALLATION

Gas-fired space heaters are clean in operation; they are easily operated and require no fuel handling. They are adaptable for use with natural gas, manufactured gas, or liquefied petroleum gas. Their construction features are similar regardless of the type of gas used. Basically, there are two types, the vented and the unvented.

VENTED UNITS are enclosed metal cabinets with either top and bottom or front and rear grilles for warm-air circulation. The flame burns in a closed combustion chamber and the gases are carried away by the heater vent. (See fig. 9-5.) The flow of heat is maintained by a motor-driven fan and is controlled by vanes, fins, louvers, or diffusers. This type of unit is more satisfactory than the unvented type because there is less danger of carbon monoxide poisoning.

The panel unit is another type of vented unit. (See fig. 9-6.) It may be recessed in either an inside or outside wall with the vent properly insulated and run up through the wall. This type of unit has the advantage of requiring less floor or ceiling space.

UNVENTED UNITS are usually the open-flame type where the gas burns in an open combustion chamber. These heaters should be used in well-ventilated places. Ventilation ensures that the carbon monoxide produced by the gas flame is removed.

Gas-fired space heaters and their connections must be of the type approved by the American Gas Association (AGA). They must also be installed according to AGA specifications. Installation factors such as the type of gas, capacity of the heater, and line pressure drops must be known to ensure proper plumbing procedure with respect to the gas service line. All newly installed piping should be tested for gas leaks. These tests should comply with NAVFAC DM3.

On vented gas units, be careful to install the venting system properly to minimize the harmful

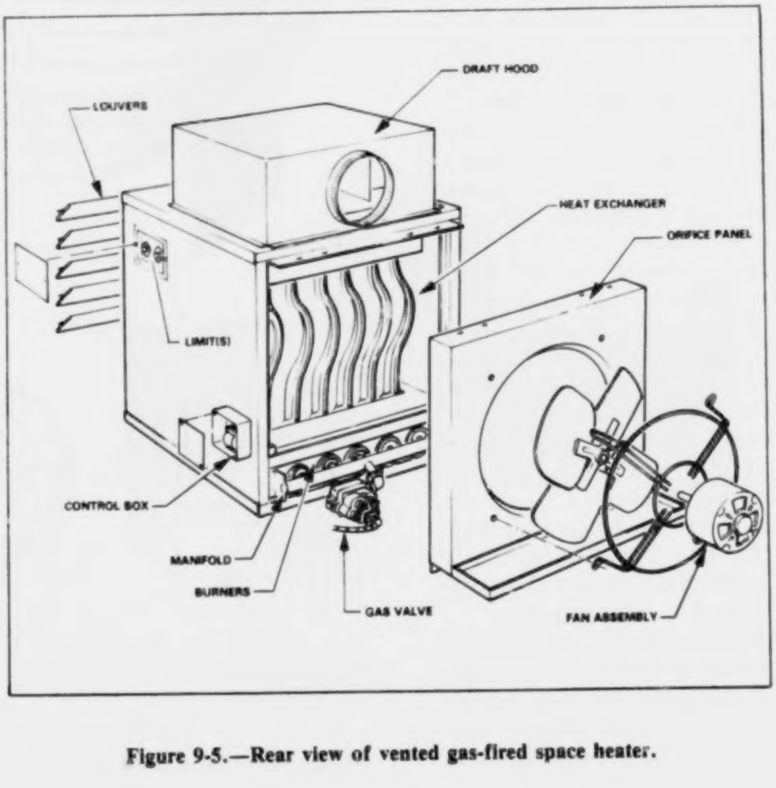

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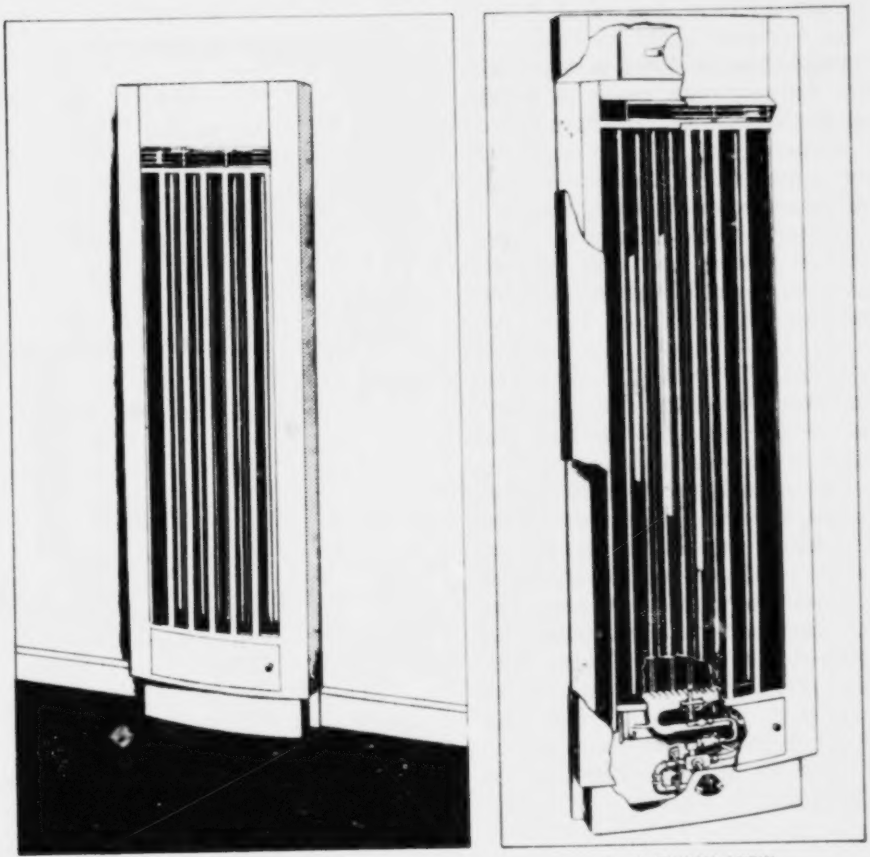
Figure 9-5.—Rear view of vented gas-fired space heater.



1. INSTALLED VIEW

2. CUTAWAY VIEW

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Figure 9-6.—Gas-fired panel space heaters.

effects of condensation and to ensure that the combustion products are carried away. During operation, the inner surface of the vent must be heated above the dew point of the combustion products. This prevents water from forming in the flue pipe. Vent sections must be installed with the male ends of the inner liner down to allow any condensation that forms to return. This is important since the burning of 1,000 cubic feet of natural gas produces approximately 12 gallons of water. For the same reason, horizontal flue pipes should have an upward pitch of at least 1 inch per running foot.

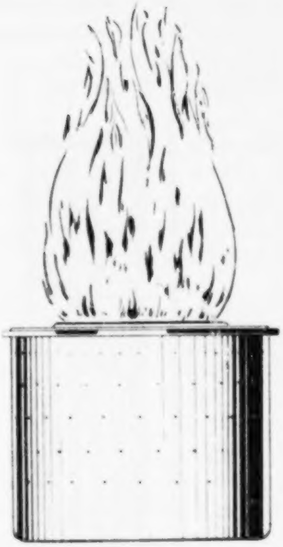
Vent pipes should be equipped with draft diverters. A diverter is a type of inverted cone through which the flue gases must pass on their way to discharge. It allows air from the heated room to be drawn into the flue pipe joining the combustion gases. This prevents excessive downdrafts or updrafts that are apt to extinguish the pilot light or possibly the main burner.

OIL-FIRED SPACE HEATERS

In areas where oil is the principal fuel, oil-fired space heaters are used for many space heating requirements. Oil-fired space heaters are very simple in construction. They consist of a burner, a combustion chamber, an outer casing, a fuel tank, and fuel control valve. An air space is provided between the combustion chamber and the outer casing. Air enters through grilles in the bottom of the heater, is heated, and passes out through grilles in the top of the unit. Some oil burning heaters are equipped with a blower and electric motor to force the heated air out into the room. They turn at a slow speed and may be either direct drive or belt driven.

Oil-fired space heaters have atmospheric vaporizing-type burners, two types of which are described briefly below. The burners require a light grade of fuel oil that vaporizes readily at low temperatures and leaves only small amounts of carbon and ash. Number 1 fuel oil is generally used. The two types of oil-fired space heaters that will be discussed are the natural draft pot and the perforated sleeve.

NATURAL DRAFT POT DISTILLATE BURNERS are widely used for space heaters, room heaters, water heaters, and so on. A cutaway view of a natural draft pot type of burner is shown in figure 9-7. In operation, the distillate (oil) is fed at the bottom of the burner, either at the center or on the sides, and is vaporized at this point by radiant heat from above. The vapors rise and mix with the air drawn through the perforated holes in the burner. During high fire conditions, the flame burns above the top combustion ring, as in figure 9-8; and under low fire conditions, the flame burns in the lower portion or pilot ring of the burner as in figure 9-9.



54.191

Figure 9-8.—High fire flame.

The PERFORATED SLEEVE BURNER consists of a metal base formed of two or more circular fuel vaporizing grooves and alternate air channels. (See fig. 9-10.) Several pairs of perforated sleeves or cylinders, one

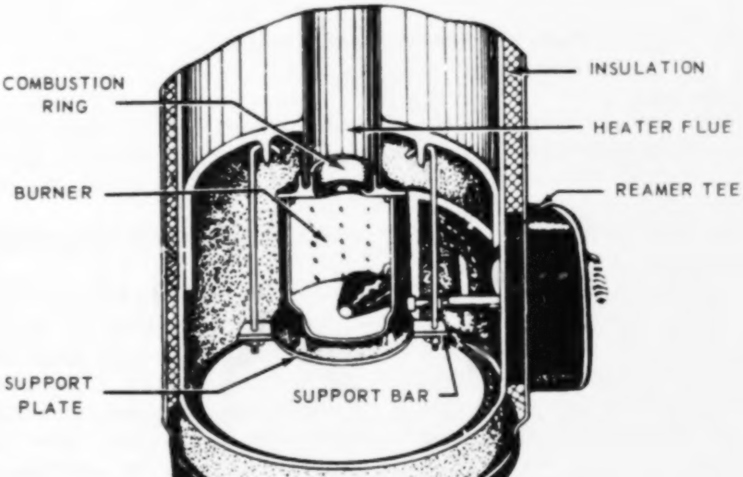


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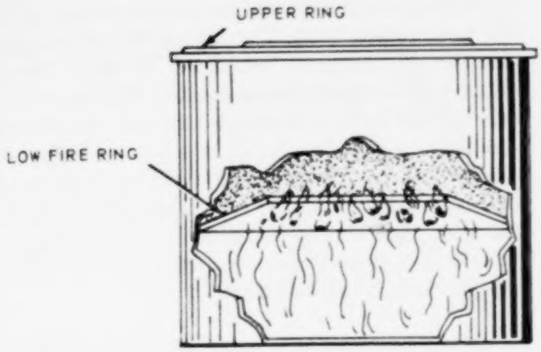
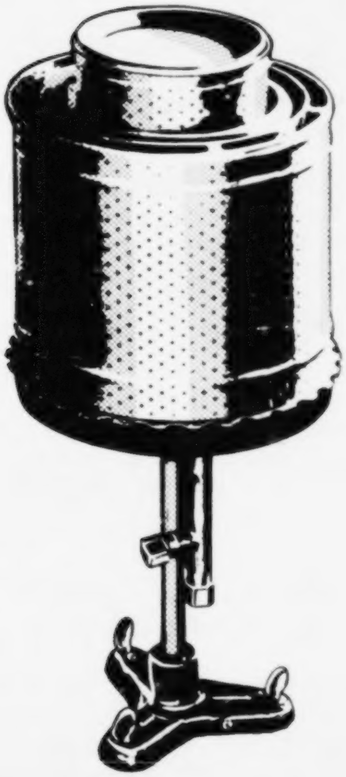
Figure 9-7.—Cutaway view of a natural draft pot type of burner.


UPPER RING
LOW FIRE RING

54.192

Figure 9-9.—Low fire flame.



54.13

Figure 9-10.—Perforated sleeve burner.

inside the other, are mounted on the base. Each pair of perforated sleeves forms a combustion chamber above its own grooves. One or more cover plates resting on top of the nested cylinders baffle the flame and close the air passage, thus forcing air through the perforations into the oil vapor chamber. In this way a large number of jets of air are introduced into the oil vapor, bringing about a good mixture. This mixture burns with a blue flame and is clean and odorless.

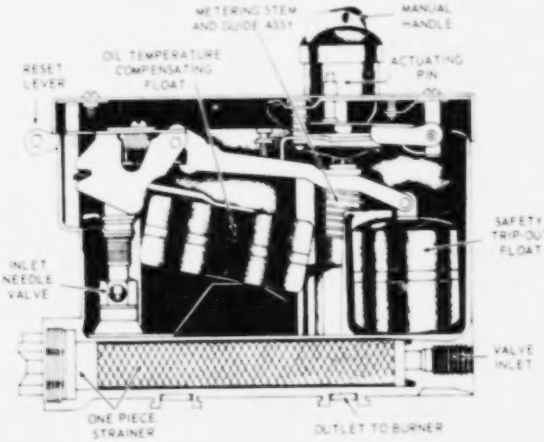
For ease in lighting, these burners usually have a short asbestos kindling wick. Some burners have a cup below the base in which alcohol is burned to provide heat for starting. The wick and alcohol are used only for lighting.

INSTALLATION

Oil burning heaters are portable and are easily moved from one location to another. For satisfactory operation, follow the installation procedures supplied by the manufacturer. In both perforated sleeve and pot type of burners, oil is fed to the burner under control of a float-operated metering valve. (See fig. 9-11.) Set the unit level so the oil can be properly distributed in the burner.

A point to remember is that: THE FUEL LEVEL CONTROL VALVE IS THE ONLY SAFETY DEVICE ON THE OIL-FIRED SPACE HEATER.

When several space heaters are installed in a building, an oil supply from an OUTSIDE TANK


METERING STEM AND GUIDE ASSY
MANUAL HANDLE
RESET LEVER
OIL TEMPERATURE COMPENSATING FLOAT
ACTUATING PIN
SAFETY TRIP-OUT FLOAT
INLET NEEDLE VALVE
VALVE INLET
ONE PIECE STRAINER
OUTLET TO BURNER

54.16

Figure 9-11.—Oil-control metering valve.

to all of the heaters is often desirable. This eliminates frequent filling of individual tanks and reduces waste from spilling. Figure 9-12 shows the principal elements of such a system and important points to consider during installation.

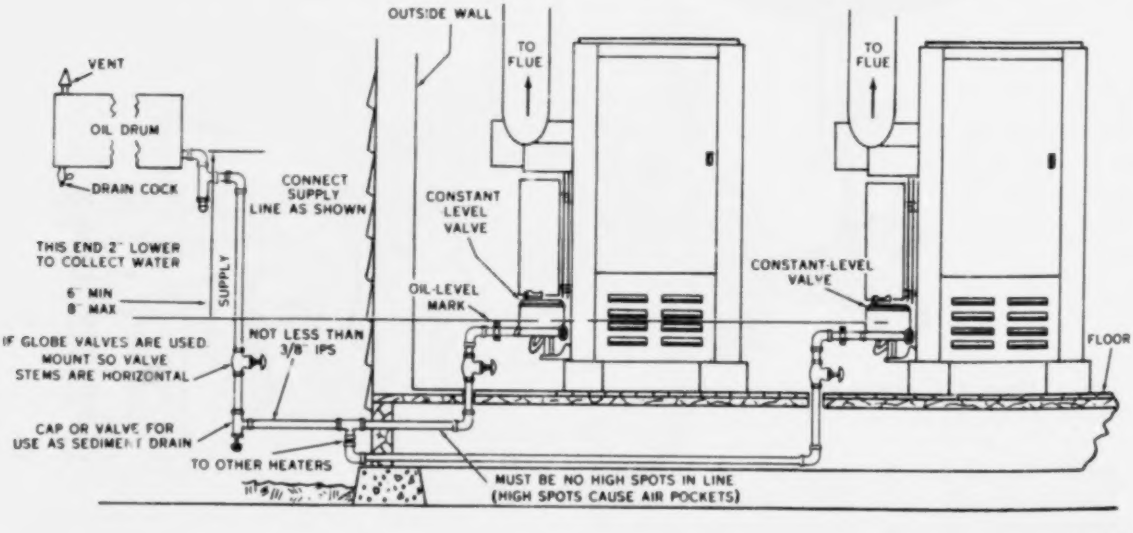
Be sure that the space heater is placed a safe distance from the wall. You also need a metal pan made of sheet metal for it to sit in. This pan catches the oil if a leak occurs. Do not use a sandbox or cement as both absorb oil and create a fire hazard. In the case of wood floors, place a piece of fire-retardant material, such as Sheetrock, on the floor underneath the metal pan. It may also be needed on the wall behind the heater if the wall is made of wood.

Since the flow of air to a vaporizing type of burner is induced by the chimney DRAFT, pay careful attention to this feature. The draft produced by any chimney depends upon the height of the chimney and the difference in temperature between the flue gas and outside air. The cross-sectional area required depends upon the volume of flue gas to be carried. Since outside air temperature varies during the heating season, arrange the chimney or flue to produce the necessary draft under the most unfavorable conditions likely to be encountered, usually an outside temperature of 60°F. Above this temperature heat is not usually required, and below this temperature draft would be increased.

Install the draft REGULATOR to maintain a constant draft adjustment for the rate at which the heaters are fired. The regulator is a swinging damper or gate with provision for adjustment. Since balance and free action are the fundamentals on which its operation depends, be sure the installation provides for these features. Install the damper section with the word *top* at the true top position. Make sure the face is plumb. When the damper regulator is installed in a horizontal or nearly horizontal run of pipe, do not use a counterweight on the damper.

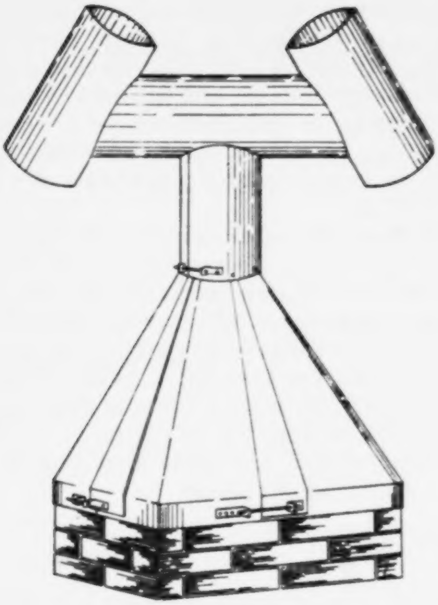
A DOWNDRAFT may seriously interfere with proper functioning of these burners. Downdraft may result when the chimney is not high enough above the roof line or is too close to other high buildings, trees, or terrain features. The chimney top must be at least 3 feet above the highest point of the building roof. If the difficulty is caused by other factors, a downdraft hood may prove effective. There are several successful designs; a simple constructed type is shown in figure 9-13.

Copper tubing is often used in an oil supply system because of its high resistance to corrosion and ease of installation. It comes in rolls of 50 to 100 feet from which the needed length is cut. Tubing sizes are listed by A.C. and R. tubing sizes, as in the case of plumbing pipe sizes.


VENT
OIL DRUM
DRAIN COCK
CONNECT SUPPLY LINE AS SHOWN
THIS END 2" LOWER TO COLLECT WATER
6" MIN
8" MAX
SUPPLY
IF GLOBE VALVES ARE USED MOUNT SO VALVE STEMS ARE HORIZONTAL
NOT LESS THAN 3/8" IPS
CAP OR VALVE FOR USE AS SEDIMENT DRAIN
TO OTHER HEATERS
MUST BE NO HIGH SPOTS IN LINE (HIGH SPOTS CAUSE AIR POCKETS)
OUTSIDE WALL
TO FLUE
CONSTANT LEVEL VALVE
OIL-LEVEL MARK
TO FLUE
CONSTANT-LEVEL VALVE
FLOOR

54.193

Figure 9-12.—Space heaters installed in series.



54.15

Figure 9-13.—H-type downdraft hood.

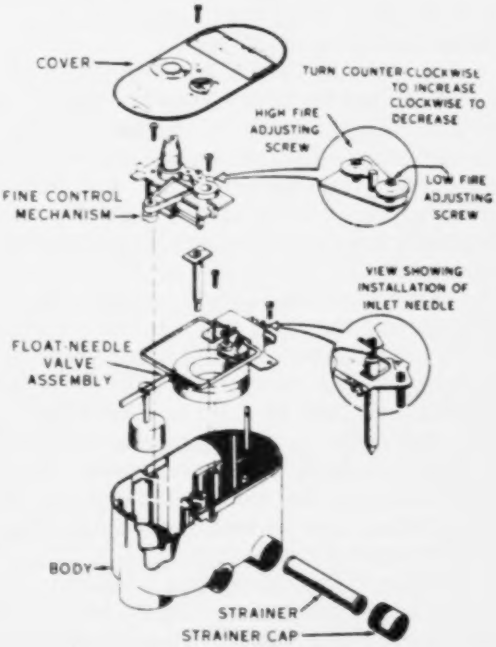
Tubing may be cut easily with either a tubing cutter or a hacksaw. The cut ends must be reamed to remove any burrs or roughness that could restrict the flow of fuel or hamper the installation of fittings. A major advantage in using copper tubing is that it can be bent easily without collapsing the tube, especially if a tubing bender is used; this cuts down on the number of fittings required.

MAINTENANCE OF SPACE HEATERS

Oil-fired space heaters require periodic cleaning. Frequent checks must be made to ensure that equipment is kept clean, because accumulations of carbon and soot can cause disastrous fires. Units should be removed when they are cleaned, so they can be cleaned inside and out. Accumulations of soot must be removed from inside the fuel pipe. All piping and tubing should be kept clean and free of oil drippings.

The pot or burner assembly may be cleaned without removing the heater. When cleaning this component, remove it through the front door opening and clean all the air holes using a soft copper wire. Do not remove all the carbon from the bottom because a small accumulation of carbon at the bottom acts as a wick and helps maintain the pilot light. In replacing the burner assembly, make sure both sides of the burner are tightened equally, so the top of the burner and the fire-retardant gasket are set firmly against the flue projection.

In checking the constant-level control valve, check the operation of the heater through a complete cycle of operation from the pilot fire position to the main fire position, and then back to the pilot fire position. Set the control valve, if it is the manual type, to high fire; and if equipped with a thermostatic device, set the thermostat above room temperature. If the heater fails to operate properly through the cycle, check the constant-level control valve and follow the manufacturer's instructions for disassembly and cleaning. A parts breakdown of the valve is shown in figure 9-14.


COVER
TURN COUNTER-CLOCKWISE TO INCREASE CLOCKWISE TO DECREASE
HIGH FIRE ADJUSTING SCREW
FINE CONTROL MECHANISM
LOW FIRE ADJUSTING SCREW
VIEW SHOWING INSTALLATION OF INLET NEEDLE
FLOAT-NEEDLE VALVE ASSEMBLY
BODY
STRAINER
STRAINER CAP

87.273

Figure 9-14.—Constant-level control valve.

Some of the common problems with pot and sleeve oil burners, their causes, and possible remedies are listed in table 9-3.

OIL BURNERS

Oil enters the burner at the center or side of the bottom of the bowl and is vaporized close to the point of entry by radiated heat from above. The vapors rise and mix with air drawn in through holes in the sides of the bowl. The fire is usually controlled manually. With high fire, the flame burns from the flame ring at the top of the pot; with low fire, it burns from the pilot ring down in the pot. (See figs. 9-8 and 9-9.) Do not let the flame burn on the bottom of the pot.

The position of the flame depends upon the quality of vapor produced. These units burn oil vapor, not liquid oil. The quantity of vapor produced depends upon the oil level in the pot and heat available to vaporize it. After vapor forms, it must be mixed with enough air to burn.

To CLEAN SOOT from the heater, take the casing and flue pipe off and remove from the heater. Some heating elements may be cleaned by simply tapping the element with a piece of wood to loosen the soot. The elements may then be removed by running a flexible hose from a vacuum cleaner through the unit. If air pressure is to be used to blow out soot, first move the heater out of the building.

The OIL-CONTROL METERING VALVE (fig. 9-11) used for these burners maintains a given level of oil in the burner to operate the heater at the rate desired. The rate is a minimum at START position of the control knob and increases progressively to maximum at HIGH position. Adjusting screws are provided for making further adjustment for either LOW or HIGH position, if necessary. Access to these screws is obtained by removing the cover plate. Initial adjustment rarely requires changing unless the grade of oil is changed. The safety float provides a safety cutoff for oil flow when the level rises above the safe limit point. If this happens after the valve is tripped by the float, determine and correct the fault; then reset the unit with the lever provided. The strainer can be removed for cleaning by unscrewing the strainer nut.

Maintenance requirements of electric space heaters can be grouped as (1) those for corrosion control and cleaning and (2) those for motors and fans. Maintenance of controls requires that you check all electrical connections for worn or damaged parts and wires for frayed surfaces; check and calibrate thermostats; and on portable units, check the safety switch that is designed to de-energize the heating element when it is accidentally tipped over. Also check the safety switch that protects the unit against overheating. Overheating is possible when airflow is obstructed. You should check and replace safety lights, as needed, that tell you when a unit is on and heating.

Heating coils and elements must be kept clean to prevent dust and other foreign matter from collecting and acting as insulating materials, thereby reducing the effectiveness of the unit. Visually check elements for pitting, broken parts, and corrosion. Parabolic reflectors should be kept polished to a mirrorlike brightness. Safety grilles should also be kept free of corrosion and rust. Lubricate motors and fans according to the manufacturer's instructions.

FURNACES

Most furnaces come complete with blower, motor, motor base, filter rack, and housing. If a base consisting of a sheet-metal bottom is furnished, follow the manufacturer's instructions for assembling the unit. If a housing without a sheet-metal bottom is furnished, fasten the blower and motor base securely to a masonry floor with lag bolts and expansion shields. Exercise care in locating the motor and blower. Be sure they are in true alignment. Allow enough distance between the motor and the blower to permit belt adjustment. If only the motor and blower are supplied, make a cabinet so that it has ample space for proper air movement. Provide doors and openings to permit oiling, adjustment, and minor repairs to the motor and blower. If a sheet-metal bottom is not installed, fasten the blower casing to a masonry floor and grout it to prevent air leakage at that point. Install a fire-retardant collar in the casing to fit snugly around the blower outlet and eliminate vibration noises from the blower. Connect the blower casing and blower boot with the same type of connection as that between the boot and the furnace casing.

The motor pulley is usually adjustable for a wide range of speeds. Adjust the speed of the blower to deliver the volume of air called for in the specifications. However, if this has been done and a change of blower speed is required, make the change by adjusting the motor pulley, then resetting the belt tension. A simple way to determine the proper volume of air is to hold a handkerchief at the top of the warm-air outlet and

Table 9-3.—Troubleshooting Chart for Pot and Sleeve Oil Burners

Problem	Probable Cause	Possible Remedy
Burner smokes	Improper fuel	Use recommended fuel
	Insufficient oil flow	Troubleshoot for low flow
	Excessive chimney draft	Check draft regulator
	Pilot casing is poorly fitted	Remove and install correctly
	Dirty burner	Clean the burner
	Excessive flue downdraft	Install downdraft hood
Burner goes out	Low oil supply	Add oil if necessary
	Plugged vent on the oil supply tank	Clean the vent
	Insufficient oil flow	Troubleshoot for low oil flow
	Improper fuel	Use recommended fuel
	Fuel inlet plugged with carbon	Clean
	Dirt in the oil control valve	Clean the valve
	Oil valve is not level	Level the valve
	Filter cartridge plugged with sludge and dirt	Clean the filter
	Excessive chimney draft	Check draft regulator
	Excessive flue downdraft	Install downdraft hood
Burner flooded	Dirty float valve	Remove and clean the float valve
	Improper operation	Instruct operating personnel on proper procedures
	Needle valve stuck	Clean or replace the valve
Low oil flow	Air trapped in oil supply line	Eliminate high points in the piping and bleed air out
	Oil control valve not level	Level the valve
	Oil may be too heavy	Use manufacturer's recommended grade of oil
	Dirt in the supply line or in the metering mechanism	Clean line and components
Low oil flow (continued)	Clogged oil strainer	Clean the strainer
	Flue inlet clogged with carbon	Remove the carbon
High fuel consumption	Improper fuel	Use manufacturer's recommended grade of oil
	Heat loss	Reduce air supply to the burner
	Heat exchanger areas caked with carbon and slag	Clean the affected areas
	Excessive chimney draft	Check the operation of the draft regulator

let the moving air raise it. Velocity should be such that the handkerchief is blown almost horizontal.

To adjust the motor pulley, loosen the setscrew (fig. 9-15) and separate the two pulley faces to decrease blower speed. Bring the faces closer together to increase speed. In locking the pulley adjustment with the setscrew, be sure to force the setscrew down on the flat surface of the pulley shaft and not on the threads.

To adjust belt tension, slide the motor on its base. Every blower motor has a means of making the tension adjustment. Unless a manufacturer specifically recommends a tighter adjustment, leave from 1 1/2 to 2 1/2 inches up-and-down slack on the loose side of the belt, depending on its length. If a V-belt is adjusted too tight, it will wear rapidly and seriously overload the motor. If it is too loose, it will slip.

Check the motor pulley and blower alignment on each installation, using a straightedge or a tight line. The motor shaft is usually long enough to allow for this adjustment. However, if the alignment adjustment cannot be made by this method, move the motor into the proper position.

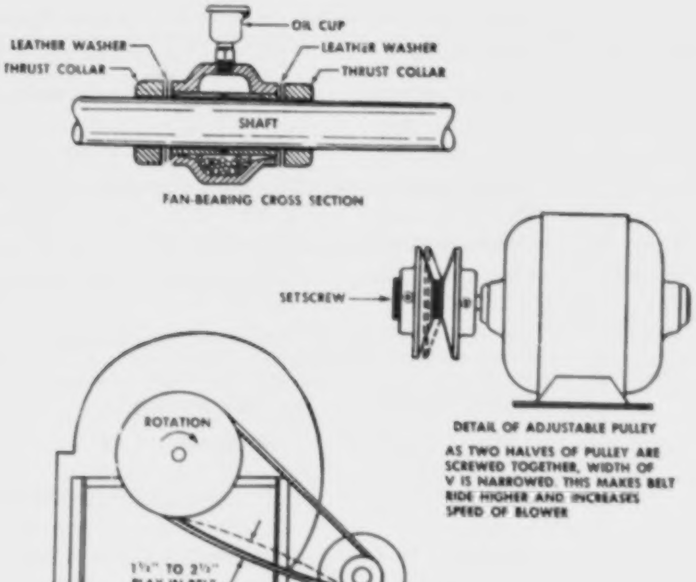
Most blowers have bearings that are self-aligning. Some, however, have bearings that are held in alignment by bolts that anchor the bearings to the blower. If of this type, check the bearing alignment; if bearings are binding, loosen the bolts, bring bearings into alignment, then retighten the bolts.

Thrust collars are locked to the shaft on each side of one of the blower bearings. These collars keep the blower wheel in alignment and, when properly set, eliminate end play.

If a thumping noise occurs in the blower, there is too much end play. This noise may be eliminated by setting the thrust collars closer. Exercise care to set collars as closely as possible without binding. With either type of bearing, remove the belt and rotate the blower wheel to be sure it rolls freely.

Oil the motor and blower bearings when the unit is placed in service, and every 3 months during the heating season. Use thin wire, such as a straightened paper clip, to open the oil passage to the shafts at each oiling.

Dirty filters impede air circulation, regardless of blower speed. If little or no air passes over the


OIL CUP
LEATHER WASHER
LEATHER WASHER
THRUST COLLAR
THRUST COLLAR
SHAFT
FAN-BEARING CROSS SECTION
SETSCREW
DETAIL OF ADJUSTABLE PULLEY
AS TWO HALVES OF PULLEY ARE SCREWED TOGETHER, WIDTH OF V IS NARROWED. THIS MAKES BELT RIDE HIGHER AND INCREASES SPEED OF BLOWER
ROTATION
1½" TO 2½" PLAY IN BELT
BLOWER BELT TENSION

87.78

Figure 9-15.—Bearing, pulley, and belt adjustments.

furnace, the building is insufficiently heated and the furnace overheats, which may result in serious damage. Inspect filters at least once each week. For replaceable types of filters, if dirt is deposited so thickly that air circulation is obviously impaired, replace the filters. If new filters are not immediately available, remove one or two filters from the blower so air can be circulated until clean filters are available.

Another way of finding filters dirty enough to replace is to remove enough filters to give the return air full-rated square-inch capacity and check the amount of air coming from the warm-air openings. If the amount of warm air has increased very noticeably, filters are dirty and should be replaced.

Most humidifiers used in warm-air installations are the pan type with a float to regulate the water level. Because of the high temperature to which the float valve is subjected, it frequently sticks in an open or closed position. To release the valve, move the float ball up and down to allow water pressure to clean the dirt or other accumulation from the seat. Frequent jiggling of this float control prevents sticking. If water is comparatively free of solids, the humidifier float seldom requires service. If the water is bad, however, you may have considerable difficulty. It is of prime importance to check the installation of the pan to see that it does not overflow on the combustion chamber or radiator of the furnace.

Install the blower and limit controls in the top of the casing and in the opening provided by the manufacturer. If the opening has not been provided for this control, install it 10 to 18 inches above the top of the combustion chamber to make it easily accessible for inspection and adjustment.

Set the blower control to stop the blower between 80°F and 90°F in the plenum chamber. Adjust the control to stop the blower at 115°F for gas or oil. The blower should run continuously when the outside temperature is 35°F or below. The more continuously the blower runs, the better the building can be heated, particularly in cold weather. A slightly higher temperature setting may be used in cold climates, where a long duct is installed, or to meet some other local condition. Keep deviation from the above recommended settings to a minimum.

Set the limit control to turn off the fire at 175°F in milder climates and 200°F in colder climates. Never set the limit control any higher than necessary to keep the building at proper temperature. Set the limit cutoff point low in mild weather and raise it somewhat as the weather gets colder.

FURNACE TROUBLESHOOTING AND GAS BURNER MAINTENANCE

Insufficient heat in an area is generally the result of a furnace malfunction. In this section you can learn to narrow the problem area by checking the symptoms relative to a specific control or unit.

1. IF NOT ENOUGH HEAT IS SUPPLIED, check the following:

a. Filters are plugged with dirt. Clean or replace the filters as instructed.

b. Blower is running too slowly because of the motor pulley adjustment or slipping of the belt. Adjust the speed or tighten the belt.

c. Blower is not operating because of a blown fuse or an overload that would stop the motor automatically. Most motors have an automatic overload protecting switch. If the belt is too tight, causing excessive pressure on bearings or thrust collars bind, the motor becomes overloaded and the overload switch turns the motor off. Except where the overload switch has a manual reset, the motor will start again when the motor has cooled sufficiently for the automatic switch to complete the electrical circuit, but will again shut off if an overload still exists. In larger motors the overload switch is in a separate box. To start the motor again, push the reset button in this overload switch. Whenever the motor is cutting out because of an overload, eliminate the overload before continuing operation of the motor. If the fuse is blown, replace it.

d. Blower running in the wrong direction. If a blower is running backwards, a small amount of air goes forward to the system. Correct the trouble by connecting internal leads of the motor according to the manufacturer's instructions.

e. Dampers in the air ducts are closed or partly closed causing air circulation to be impeded. Frequently handles have been removed from inside if the duct dampers and the position for these dampers cannot be determined without checking through a small opening made in the duct for that purpose. If this condition exists, check the position of the dampers and replace the handles if available.

2. IF ROOMS ARE FIRST HOT, THEN COLD, check the following:

a. Blower control is set too high. The blower does not start until the furnace is very hot and a surplus of heat is then blown into the building. Set the blower control down according to recommended blower control settings. To test for this condition, turn on the manual switch controlling the blower and let the blower run continuously regardless of the plenum chamber temperature. If this relieves the condition, the blower control is set too high. Lower the temperature setting as needed.

b. Room thermostat is out of adjustment. This allows too great a temperature difference between the time when the thermostat makes contact to call for heat and when it breaks contact to close down the fire. Adjust the thermostat according to the manufacturer's recommendations.

c. Limit control is set too high. Adjust the control.

3. IN CASE OF A COLD DRAFT ON THE FLOOR, check the following:

a. A window or a door is open or loose-fitting windows are admitting too much cold air. Close the door or window, tighten loose-fitting windows, and seal cracks.

b. Filters are plugged and insufficient air is being delivered. In this case, air that does come from the furnace into the room is very hot. This causes air at the floor line to be cold because it is not being drawn off the floor into the furnace fast enough. Clean or replace the filters.

c. Blower control is set too high. Adjust the control.

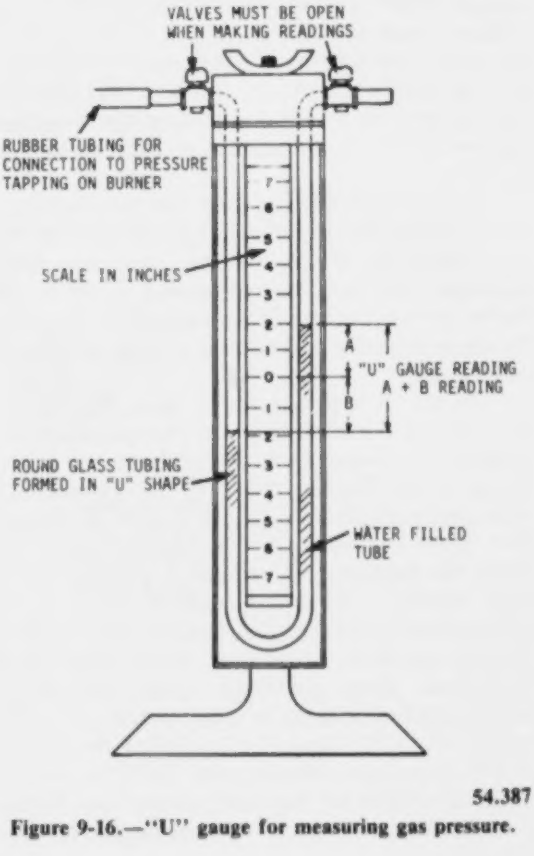
4. IF THE BLOWER CONTROL FAILS TO WORK, check operation of the contacts. If the control fails to make or break contact properly, it has probably been ruined by overheating the furnace. However, the control may have been tampered with by unauthorized personnel. Install a new control.

CAUTION: Do not operate a forced-warm-air furnace without a blower control.

5. IF THE LIMIT CONTROL FAILS TO WORK, check operation of the contacts. The reason for failure of this control is the same as that for the blower control. If new controls are not immediately available, temporary heat can be obtained by wiring across the blower- and limit-control terminals in a suitable manner to operate the blower continuously. Use this method ONLY IN AN EMERGENCY.

6. IF THE BLOWER STARTS AND STOPS TOO FREQUENTLY, check the settings of the blower control. If the blower starts and stops at intervals of 2 or 3 minutes, motor life is shortened. This also overheats the overload switch in the blower control. Increase by 10 °F the differential between starting and stopping temperatures on the blower control. This usually corrects the difficulty.

Gas burners should be inspected to note the appearance of the gas flame. A yellow flame indicates a poor fuel-air mixture and suggests that carbon is being formed as a result of incomplete combustion. Flame adjustments are made by first adjusting the pressure regulator. The gas pressure is measured by using a U-gauge (manometer), as shown in figure 9-16; the regulator is adjusted to the manufacturer's specifications. To adjust the pressure regulator, remove the cap from the top


VALVES MUST BE OPEN WHEN MAKING READINGS
RUBBER TUBING FOR CONNECTION TO PRESSURE TAPPING ON BURNER
SCALE IN INCHES
7
6
5
4
3
2
1
0
1
2
3
4
5
6
7
A
B
"U" GAUGE READING A + B READING
ROUND GLASS TUBING FORMED IN "U" SHAPE
WATER FILLED TUBE

54.387

Figure 9-16.—"U" gauge for measuring gas pressure.

of the pressure regulator and turn the slotted disk clockwise to increase the pressure and counterclockwise to decrease it. The flame is then adjusted for proper characteristics by using the movable burner dampers. Adjust the air to get a soft blue flame with luminous tips, then increase it slightly until the yellow just disappears.

You must clean the unit often if the flame is not adjusted correctly. You should inspect the burner orifices and correct any condition that restricts the flow of gas or changes direction of the gas flow. Also inspect the interior of the combustion chamber and the passages in the heating unit for soot and carbon formations. There should be no formation of soot when the gas is completely burning.

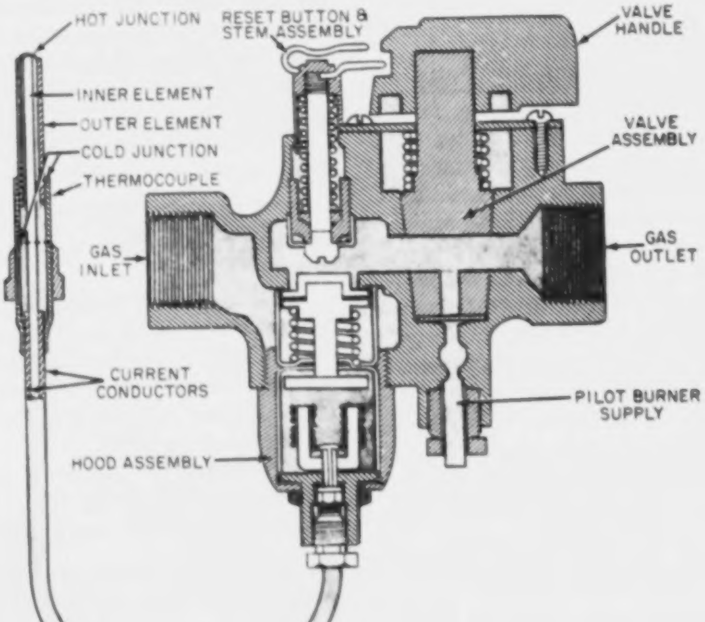
Gas burner ports must be blown out with air when they become partially plugged with dust or dirt. A yellow flame indicates they are plugged up. The ports can also be cleaned with a drill of the same size by pushing it into each individual hole. Main burner orifices can be cleaned in the same manner.

Heat exchange tubes must be cleaned periodically. They can be cleaned by the use of a wood lath or stick shaped to fit the curvature of the tubes; push this stick up and down along the sides of each tube. Also, a vacuum cleaner can be used by running the flexible suction hose along the tubes. Compressed air is suitable only after the tubes are removed from the building.

Pilot orifices may become plugged, especially when the gas contains a high degree of impurities. When there is no air in the gasoline and the orifice is free of dirt particles, the pilot should burn with a soft blue flame. The orifice can be cleaned with air or by a tip cleaner. Do not enlarge or distort the orifice when cleaning.

Automatic gas-fired space heaters must have a fail-safe type of gas control valve to ensure a 100 percent shutoff if the pilot or the main fire is extinguished. Two types of valves are used: the manual and automatic shutoff valve and the pilot safety switch solenoid valve.

Figure 9-17 shows a combination manual and automatic shutoff valve (pilot safety valve). The automatic valve is energized by a small current generated from a thermocouple when its outer element is exposed to a direct flame. Once the pilot burner is lighted for approximately 1 minute,



87.265

Figure 9-17.—Pilot safety valve.

the thermocouple reaches a high enough temperature to energize the electromagnet and hold the gas supply valve open. This process continues as long as the pilot flame burns. When the pilot flame goes out, the thermocouple cools. The electromagnet is then de-energized, and the gas supply is shut off.

The following procedures are recommended when a pilot safety valve does not function:

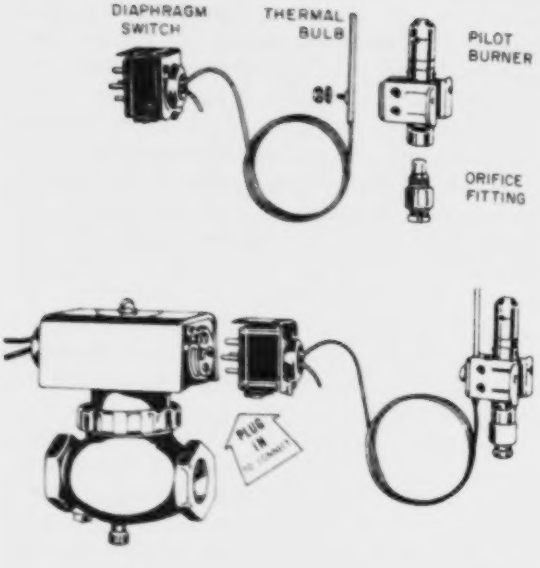
1. Check the pilot burner; clean the pilot orifice air opening to ensure a steady blue flame.
2. Check the location of the thermocouple with reference to the pilot flame; make certain the pilot burner flame envelopes 3/16 inch to 1/2 inch of the thermocouple tip to ensure optimum voltage output; also ensure that neither the pilot flame nor the main burner flame heats the thermocouple cold junction.
3. Remove the hood assembly; clean the cone of the thermocouple lead and socket of the connector stud on the hood of the valve to assure good electrical contact; reassemble and tighten the connection one-fourth of a turn beyond finger tight.

Try the safety valve at this point. If it still does not function, test the thermocouple using either of the following procedures:

1. Determine the exact millivoltage being generated by the thermocouple; after the pilot flame has been burning normally for at least 5 minutes, disconnect the thermocouple from the hood assembly (hold the reset to ensure continued flame); using an ohmmeter on the millivolt scale, attach the leads to the thermocouple correctly to measure the millivoltage; compare the reading with the manufacturer's specifications to determine if the thermocouple is functioning properly.
2. Use a new thermocouple as a check against the old one; if the valve functions with the new thermocouple, the old one must be replaced.

If, after completing the above procedures, the safety valve still does not function, replace the complete assembly.

Figure 9-18 shows a pilot safety switch solenoid valve. This valve uses a thermal fluid bulb instead of a thermocouple. After the pilot burner has been lighted for about 1 minute, enough pressure develops in the thermal bulb to actuate the diaphragm and close the contact in the safety switch on the solenoid valve. The solenoid valve is now operative if the control circuit is energized. If the pilot flame goes out, the bulb cools, thereby reducing the pressure in the diaphragm and opening the contacts in the safety switch. This prevents the solenoid valve from opening, and also causes it to close if it was open, thereby cutting off the gas supply to the main burner.



87.268

Figure 9-18.—Pilot safety switch assembly.

The following procedures are recommended when a pilot safety switch does not function:

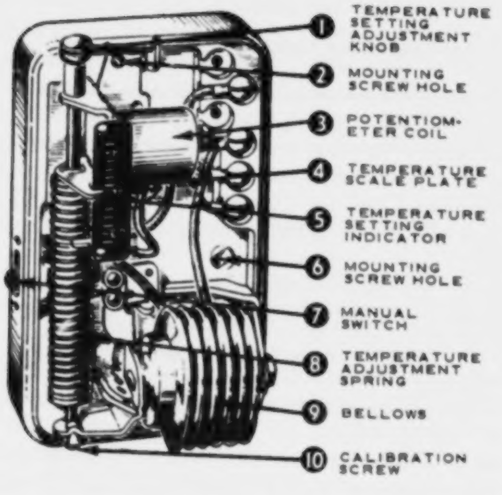
1. Check the pilot burner; clean the pilot orifice and air opening to ensure a steady blue flame.
2. Check the location of the thermal bulb to ensure proper heating by the pilot flame.
3. Check to see that the pilot switch is plugged securely into the valve's electrical components.
4. Inspect the bulb and the capillary visually for breaks or cracks.
5. Replace the assembly if the above procedures do not correct the condition or if the components remain inoperative.

Some of the most common difficulties, the usual reasons they occur, and possible remedies are listed in table 9-4.

Gas-fired furnaces require very little attention. Most requirements that arise are related to the burner and the burner control system. The most valid information on maintenance and troubleshooting is the manufacturer's instructions.

Table 9-4.—Troubleshooting Chart for Gas-Fired Space Heaters

Problem	Probable Cause	Possible Remedy
Motor does not run	Incorrect current	Check and correct
	Insecure wiring	Rewire properly
	Defective bearing	Replace and lubricate
Motor runs intermittently	Thermal overload protectors cutting out	If no external cause, such as improper current, can be found, replace the motor
Excessive fan and motor noise	Bent fan blade	Straighten by hand or replace if serious
	Excessive end play in shaft	If end play exceeds 1/32 inch, repair or replace
Solenoid valve hums or flutters	Installed backwards	Check arrow on valve body and correct if required
	Poor electrical connection or faulty solenoid	Check, correct, or replace
Burner does not ignite	Faulty pilot burner, thermocouple, or thermal bulb	Check, correct, or replace
	Inoperable solenoid valve	Impart current across the leads of the valve. A click indicates satisfactory operation. Replace solenoid if necessary
Delay in main burner operations (2 to 3 min) after fan starts	Malfunctioning limit switch	Replace limit switch
Improper burning of main burner	Primary air incorrectly set	Adjust primary air after the unit has been burning for 10 to 15 minutes. Adjust the shutter down until a yellow tip appears on the flame, then open the shutter until the yellow tip disappears
	Incorrect orifice size	Check manufacturer's specifications for the correct size and replace
	Incorrect gas pressure	Check manufacturer's specifications regarding correct pressure for the gas being used. Measure pressure and adjust pressure regulator to correct condition
Pilot fails to light or won't stay lit	Stopped pilot line	Clean line or replace, if required
	Excessive draft	Eliminate draft
	Low gas pressure	Check pressure regulator or tank level, if LPG


1 TEMPERATURE SETTING ADJUSTMENT KNOB
2 MOUNTING SCREW HOLE
3 POTENTIOMETER COIL
4 TEMPERATURE SCALE PLATE
5 TEMPERATURE SETTING INDICATOR
6 MOUNTING SCREW HOLE
7 MANUAL SWITCH
8 TEMPERATURE ADJUSTMENT SPRING
9 BELLOWS
10 CALIBRATION SCREW

87.280

Figure 9-19.—Vapor pressure or bellows thermostat.

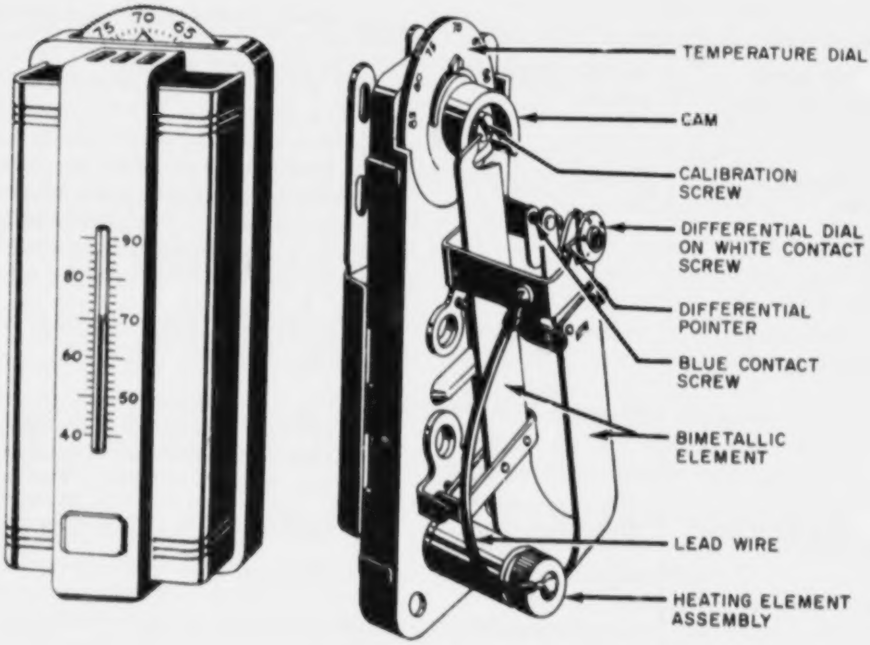
Maintenance information given earlier in this chapter on gas-fired space heaters is also applicable here. Therefore, components that were discussed previously, such as pilot safety valves and thermocouples, are not recapped. However, three additional controls—the thermostat, the fan control, and the limit control—are covered in the paragraphs below.

THERMOSTAT

The thermostat is an operating control that actuates and regulates the operation of the burner to meet heating requirements. Comfortable temperature and economical use of fuel depend upon the proper performance of the thermostatic control.

There are three types of thermostats: vapor pressure, bimetallic expansion, and mercury bulb. The vapor-pressure type contains a volatile fluid, such as sulfur dioxide, sealed in when the fluid vapor pressure changes. A vapor pressure or bellows thermostat is shown in figure 9-19.

A typical bimetallic room thermostat is shown in figure 9-20. It has, as do many others, an adjustable operating differential and a built-in heating element. The heating element applies heat to the temperature-sensing


75
70
65
90
80
70
60
50
40
TEMPERATURE DIAL
CAM
CALIBRATION SCREW
DIFFERENTIAL DIAL ON WHITE CONTACT SCREW
DIFFERENTIAL POINTER
BLUE CONTACT SCREW
BIMETALLIC ELEMENT
LEAD WIRE
HEATING ELEMENT ASSEMBLY

87.281

Figure 9-20.—Bimetallic thermostat.

device when the furnace is heating. This allows the thermostat to anticipate the response of the heating system, and thus, prevent overshooting of the room temperature.

A bimetallic thermostat that has a clock control is shown in figure 9-21. The clock can be adjusted to change the thermostat setting at any time desired. Tests have shown that reducing night thermostat settings 10 degrees saves as much as 10 percent in fuel costs. The procedure for setting the day-night controls is presented in figure 9-21.

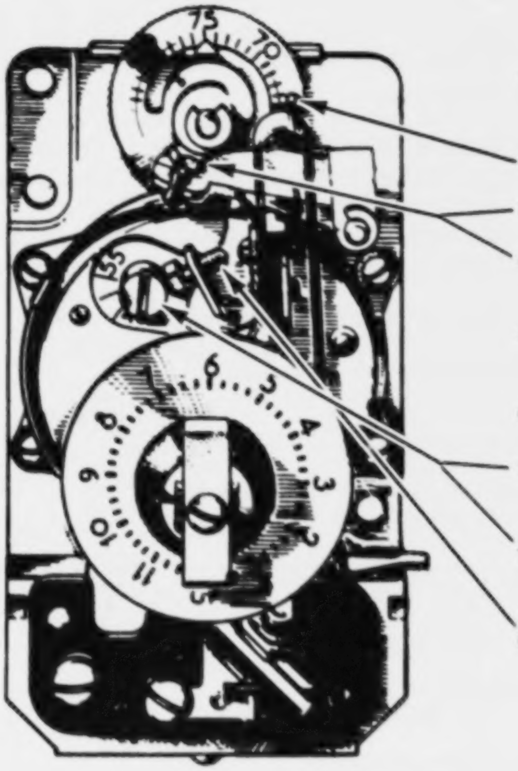
The following pointers of installation and calibration apply to most thermostats:

1. Always install a thermostat on an inside wall at eye level, or about 4 1/2 feet above the floor, and in a place where it is affected by average space temperature.

2. Ensure there is free circulation of air at the point of mounting and that the thermostat is unaffected by drafts or by heat sources.

3. Forbid anyone except qualified personnel to make adjustments to thermostats. Adjustments should be made in small, gradual steps, waiting for at least two cycles of operation—usually about 1 to 1 1/2 hours—before ascertaining the new accuracy of performance.

4. Calibration can be accomplished by hanging a precision thermometer within 2 inches of the thermostat. Allow about 15 to 30 minutes for the thermometer and thermostat to adjust to the existing temperature. The thermostat contacts should close when the control knob, or dial, is set at the temperature indicated by the test thermometer.



1 AFTER REMOVING COVER, REPLACE WINDING KNOB AND TURN IT ↶ AS FAR AS IT WILL GO.

2 TURN DAY DIAL TO ROOM TEMPERATURE.

3 TURN DAY CALIBRATION SCREW ↶ TO OPEN CONTACTS.

4 THEN TURN IT SLOWLY ↷ UNTIL CONTACTS JUST MAKE. NOW DAY DIAL IS CALIBRATED.

5 STEP BACK AND WAIT A FEW MINUTES FOR EFFECT OF BODY HEAT ON THE BIMETAL TO DISSIPATE.

6 TURN WINDING KNOB ½ TURN ↷.

7A SET BOTH THE DAY DIAL *(Step 2)* AND THE NIGHT DIAL AT 65°.

7B SET THE DAY DIAL *(Step 2)* AT 60° AND THE NIGHT DIAL AT 55° *(high end of scale).*

8 TURN NIGHT CALIBRATION SCREW SO THAT THE DAY CALIBRATION SCREW *(Step 3)* JUST TOUCHES ITS CAM.

87.282

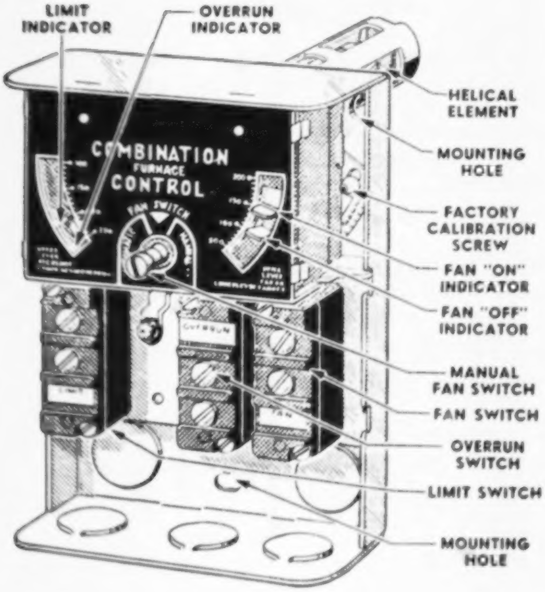
Figure 9-21.—Clock thermostat.

If calibration is required, follow the manufacturer's instructions. Troubleshooting information for thermostats is given in table 9-5.

FAN CONTROL

A thermostatic fan switch is required on most heating systems that use air-circulating fans. The fan switch serves two functions: it prevents the fan from distributing cool air before the furnace has heated to operating temperature, and it keeps the fan in operation after the burner has been shut off until all heat has been removed from the furnace. A typical fan control unit is shown in figure 9-22.

The unit may be a subassembly of the furnace or it may be installed in the air outlet duct connection of the plenum nearest the furnace. (See fig. 9-23.) This position allows it to always receive warm air by gravity before the fan comes on. Ensure that it is not so close to the heating section that it is seriously affected by heat radiated from the combustion area.


LIMIT INDICATOR
OVERRUN INDICATOR
COMBINATION FURNACE CONTROL
FAN SWITCH
HELICAL ELEMENT
MOUNTING HOLE
FACTORY CALIBRATION SCREW
FAN "ON" INDICATOR
FAN "OFF" INDICATOR
MANUAL FAN SWITCH
FAN SWITCH
OVERRUN SWITCH
LIMIT SWITCH
MOUNTING HOLE

87.284

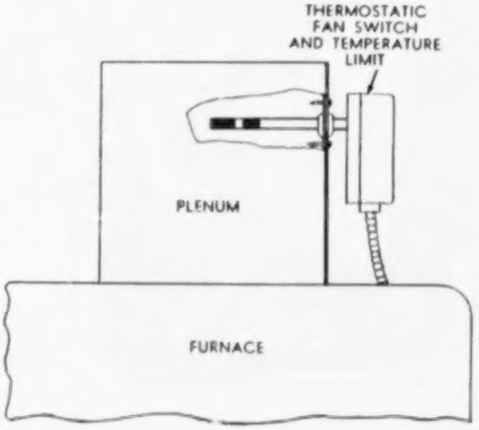
Figure 9-22.—Combination fan and limit control.

For maximum efficiency, operating conditions, and comfort, the fan control should be set as low as possible without discharging cold air. Best results are generally obtained with the ON setting at 140°F and the OFF setting at 110°F. The differential should be 25°F to 30°F. Ensure the settings agree with the manufacturer's instructions.

LIMIT CONTROL

A high-temperature limit control may be included as part of the heating equipment, or it may be a separate component in the outlet duct or plenum. In warm-air heating equipment, it is normally combined with the fan control as a single fan and limit control device. Both the fan switch and the limit switch are actuated by a common helix. This helix is a bimetallic strip in the form of a spiral. Some are right-hand wound and others, left-hand wound. The strip is made by welding two pieces of dissimilar metals, such as brass and Invar. Below a certain predetermined temperature, this strip does not bend or deflect. When the strip is heated, it bends in the direction of least expansion.

The setting should be consistent with the manufacturer's instructions. NAVFAC MO-114, *Building Maintenance, Plumbing, Heating, and Ventilation*, recommends a setting of 175°F for limit switches on continuous air circulation systems.


THERMOSTATIC FAN SWITCH AND TEMPERATURE LIMIT
PLENUM
FURNACE

87.285

Figure 9-23.—Installation of fan control unit.

Table 9-5.—Troubleshooting Chart for Thermostats

Problem	Probable Cause	Possible Remedy
Thermostat fails to energize heating system	Setting too low	Check and increase setting
	Wired incorrectly	Correct wiring
	Loose or broken wiring	Replace or repair wiring
	Loose unit or mounting plate	Level and tighten mounting screws
	Dirty contacts	Clean contacts
	Affected by warm draft	Relocate
	Mercury tube broken	Replace thermostat
	Improper type for job	Replace with proper type
Thermostat fails to de-energize heating system	Setting too high	Check and decrease setting
	Affected by cool draft	Relocate
	Improper type for job	Replace with proper type
	Wired incorrectly	Correct wiring
	Contacts fused together	Replace unit
	Not level (mercury switch type)	Level and tighten mounting screws
	Wiring shorted	Locate short and repair
Room temperature doesn't reach thermostat setting or else exceeds the setting	Defective dial	Calibrate or replace unit
	Improper type for job	Replace with proper type
	Thermometer reading incorrect	Replace unit
	Defective components	Replace unit
	Heating components too small or too large for area	Check and correct if feasible
System Short-cycles	Improper type for job	Replace with proper type
	Dirty contacts	Clean contacts
	Incorrectly set thermostat heater	Adjust or replace
	Heating components too large for area	Decrease output

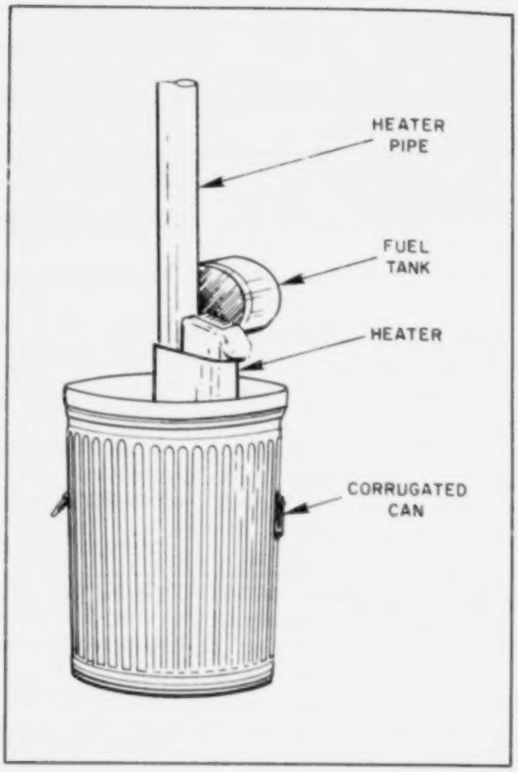
A typical gas burner control circuit, including the thermostat, limit and fan control, and the pilot safety switch, is shown in figure 9-24.

IMMERSION CAN HEATERS

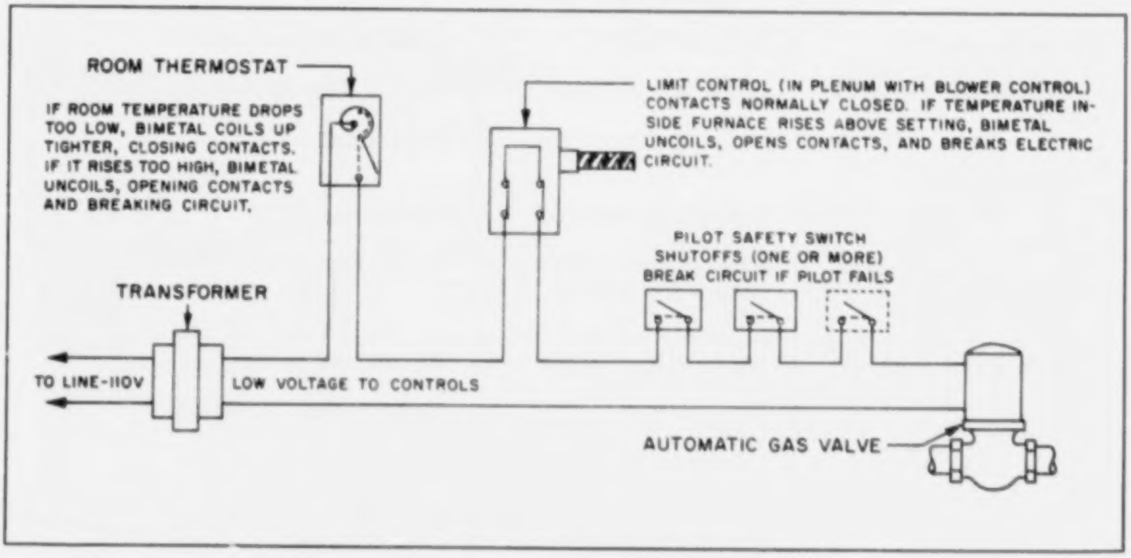
Immersion, liquid fuel-fired heaters can be used in corrugated cans and in tank trailers. The main purpose of these heaters is to supply a field unit with hot water that is safe and economical. As a Utilitiesman, you will work with the type of immersion heater used in corrugated cans, so it is with this type that we are concerned here.

One immersion heater that can be installed in corrugated cans is model FSN 454000-266-6835. The instructions in this section on immersion heaters apply to this model. An immersion heater installed in a corrugated can is shown in figure 9-25. The locations of various major parts of the immersion can heater are shown in figure 9-26.

The body of the corrugated can heater is of watertight, sheet steel construction and consists of a doughnut-shaped combustion chamber and a stack assembly welded together. A vertical partition divides the stack

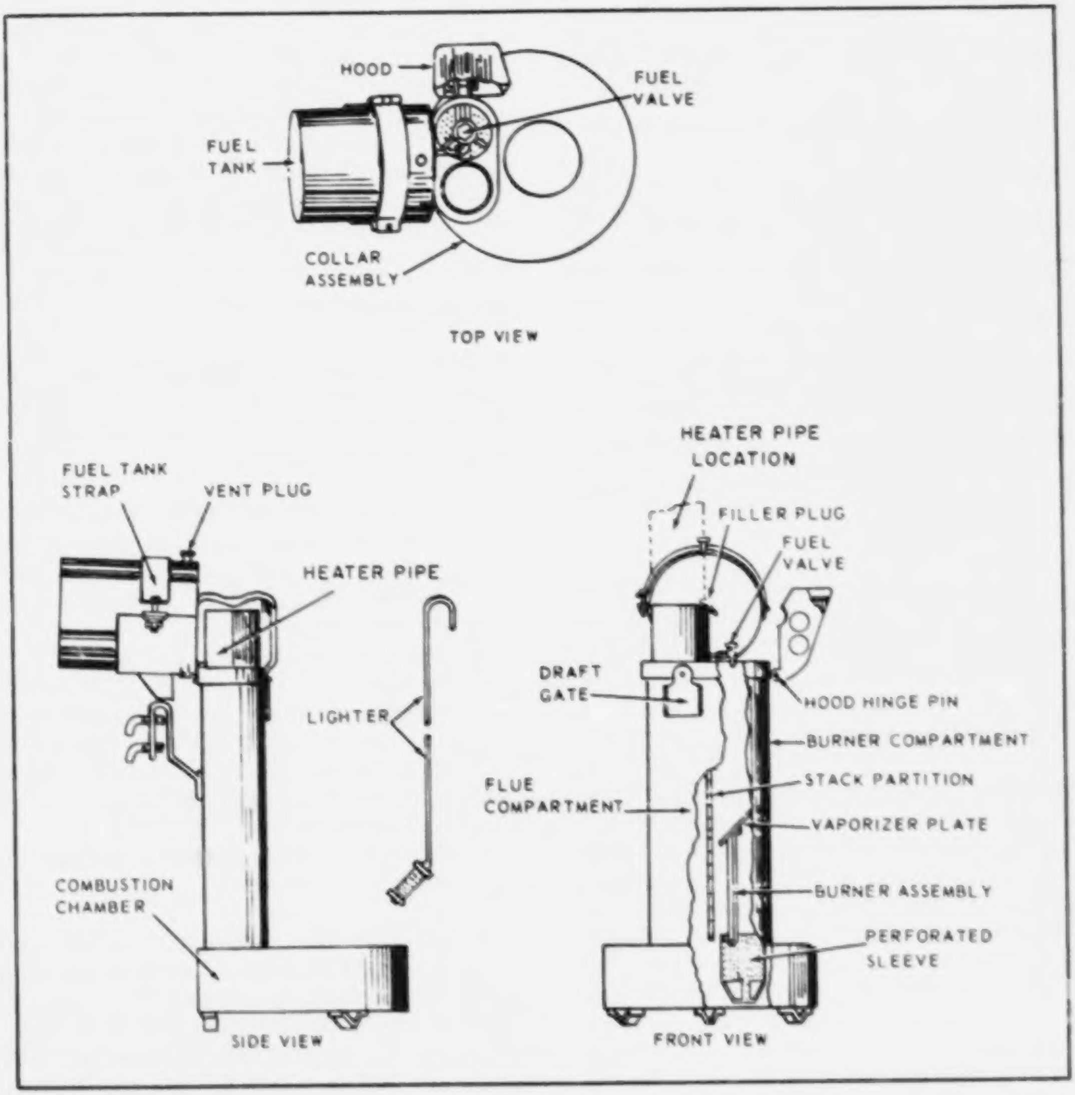

HEATER PIPE
FUEL TANK
HEATER
CORRUGATED CAN

48.75
Figure 9-25.—Immersion heater installed in corrugated can.


ROOM THERMOSTAT
IF ROOM TEMPERATURE DROPS TOO LOW, BIMETAL COILS UP TIGHTER, CLOSING CONTACTS. IF IT RISES TOO HIGH, BIMETAL UNCOILS, OPENING CONTACTS AND BREAKING CIRCUIT.
LIMIT CONTROL (IN PLENUM WITH BLOWER CONTROL) CONTACTS NORMALLY CLOSED. IF TEMPERATURE INSIDE FURNACE RISES ABOVE SETTING, BIMETAL UNCOILS, OPENS CONTACTS, AND BREAKS ELECTRIC CIRCUIT.
PILOT SAFETY SWITCH SHUTOFFS (ONE OR MORE) BREAK CIRCUIT IF PILOT FAILS
TRANSFORMER
TO LINE-110V
LOW VOLTAGE TO CONTROLS
AUTOMATIC GAS VALVE

87.283
Figure 9-24.—Typical gas burner control circuit.

into two compartments: the burner compartment that houses the burner and the flue compartment through which combustion gases leave the heater. The partition between the two stack compartments extends to the bottom of the heater and causes air entering the chamber from the burner compartment to circulate completely around the chamber before leaving by way of the flue compartment. A swing type of draft gate is on the side of the flue compartment near the top. The hanger is a length of bar steel welded to the body of the heater. It is bent to fit the rim of the can and has two clamping hook bolts to ensure mounting on the can. An instruction plate is on the hinged hood (fig. 9-26) that covers the top of the burner compartment. The vaporizer plate of the downdraft burner consists of a 3/32-inch layer of absorbent fire-retardant material sandwiched between two perforated ovals of corrosion-resistant steel. The fuel tank is held


HOOD
FUEL VALVE
FUEL TANK
COLLAR ASSEMBLY
TOP VIEW
HEATER PIPE LOCATION
FUEL TANK STRAP
VENT PLUG
HEATER PIPE
FILLER PLUG
FUEL VALVE
DRAFT GATE
HOOD HINGE PIN
LIGHTER
BURNER COMPARTMENT
FLUE COMPARTMENT
STACK PARTITION
VAPORIZER PLATE
COMBUSTION CHAMBER
BURNER ASSEMBLY
PERFORATED SLEEVE
SIDE VIEW
FRONT VIEW

54.11

Figure 9-26.—Major parts of the immersion can heater.

in place by a cradle and strap assembly. The fuel tank is equipped with a valve assembly, a vent plug, and a filler plug, all on the same end of the cylindrical tank. The heater is equipped with an 8-foot heater pipe that consists of four sections of pipe. The perforated cylinder on the end of the lighter is filled with absorbent fire-retardant material. The immersion heater uses leaded or white gas as its normal fuel. Additional information on the immersion heater is given below.

CAPACITIES	
Fuel tank	2.2 gallons
Heat output	35,000 British thermal units
Cubage, crated	5.6 cubic feet
DIAMETER	
Combustion chamber	15 inches
Pipe	4 inches
LENGTH	
Burner	12 3/8 inches
Heater only	30 inches
Heater with fuel tank	33 3/4 inches
Heater with pipe section	9 feet 8 inches
WEIGHT	
Complete	44 pounds
Crated	60 pounds

DIFFERENCE IN MODELS

Basically, all immersion heater models are the same in construction and application. However, the primary difference lies in the method by which each heater is preheated and ignited. For example, to light the immersion heater, a lighter torch must be manually inserted first in the flue compartment, and then into the burner compartment. The model 447-2EX immersion heater has a lighter cup that is mechanically pivoted inside the burner compartment. The lighter cup pivot forms a handle and extends outside the burner compartment. The operator needs only to move the handle to pass the lighter cup from the flue compartment to the burner compartment.

INSTALLATION

Before installing an immersion heater, be sure you check the entire heater assembly for signs of physical damage. See that the heater is properly assembled, secure, clean, correctly adjusted and shows no signs of a fuel leak. Select a site that is level and as sheltered as possible.

Install the fuel tank in the cradle and strap assembly and secure it with the wing nuts provided. Do NOT attempt to install a heater with a full tank of fuel because this unbalances the heater and causes it to fall. Place the burner in the burner compartment with the vaporizer plate end facing up. Now attach the four 2-foot sections of heater pipe (stovepipe) to the collar on the heater. Attach the heater to the can and tighten the locking screws or thumbscrews. Fill the can with water to 6 inches below the collar assembly of the heater. If necessary, snow may be put into the can and be melted into water. Correct deficiencies, if any, before placing the heater in service.

OPERATION

When putting the immersion heater into operation, preheat the flue. The following procedures provide a guide for preheating the flue of an immersion heater:

1. Open the vent plug as far as possible.
2. Soak the lighter in a mixture of half gasoline and half engine oil. Do NOT saturate the lighter by holding it under the fuel drip valve.
3. Use a match to ignite the lighter.
4. Swing the draft to one side and insert the burning lighter into the flue compartment. The heat from the lighter causes a draft down the burner compartment, around the combustion chamber, and up and out the flue compartment.
5. Remove the lighter in about 2 minutes; then close the draft gate.

Immediately after preheating the flue, place the burning lighter on top of the vaporizer plate. As a safety measure when doing this, make sure you wear gloves. Now open the fuel valve slightly and allow fuel to drip on the vaporizer plate. Adjust the flue valve until it flows in rapid drops but not in a fine stream. Leave the lighter in the burner compartment until its flame burns out; then remove the lighter. Make the final adjustment of the fuel to obtain a desired flame. Then close the hood and leave it closed during operation. And finally, check for and wipe up spilled fuel.

CAUTION: DO NOT EXPOSE YOUR FACE TO THE BURNER CHAMBER WHILE LIGHTING.

When you want to stop an immersion heater, first close the fuel and vent valves. Next, remove the stack and fuel tank from the heater assembly. Now remove the heater from the can and turn it upside down, so fuel in the combustion chamber can drain out.

During extremely cold weather, operate the heater under a shelter when possible. Be sure to pipe exhaust fumes outside. When the heater must be operated outside, provide a windbreak, such as a tent, building, truck, or tarpaulin. Leave a lighter burning in the flue compartment for about 4 or 5 minutes, instead of the usual 2 minutes when preheating the flue.

When operating in very hot weather, be most careful in lighting and operating heaters, because of rapid evaporation of the fuel under these conditions. Under tropical conditions, remove condensation from heaters with dry clothes to keep the equipment as free of moisture as possible.

When operating in heavy rainfall areas, upend the heater before each operation to drain water from the combustion chamber. Protect the heater with an overhead shelter whenever possible. Remember, do NOT expose the burner to moisture. The asbestos layer in the burner absorbs water and interferes with the operation of the heater.

PREVENTIVE MAINTENANCE

To ensure that the immersion can heater is always ready for operation, inspect it systematically so defects may be discovered and corrected before they result in serious damage or failure. Various preventive maintenance checks and services to be performed are listed in table 9-6. More pointers on the care of the immersion heater are given below.

Wipe dust and grease off the heater body, using a clean cloth. When rust spots are present, remove the spots with a fine grade of sandpaper. Check the heater body for dents and open seams. Beat out dents and have welds repaired as necessary. Repaint the exterior surfaces of the heater, if needed. Do NOT paint the heater below the waterline. Furthermore, do NOT paint the interior surfaces or any part of the heater pipe.

Clean the vaporizer plate of the burner and perforated sleeve with a stiff-bristle brush. Remove carbon, grit, or other foreign matter from holes in the burner. Check the burner for corrosion and for damages, such as distortion,

Table 9-6.—Preventive Maintenance Checks and Services—Immersion Can Heaters

ITEM NUMBER	INTERVAL						B–BEFORE OPERATION A–AFTER OPERATION M–MONTHLY D–DURING OPERATION W–WEEKLY Q–QUARTERLY	
	OPERATOR				ORG.			
	DAILY				M	Q	ITEM TO BE INSPECTED	PROCEDURE
	B	D	A	W				
1	X		X				Fuel tank	Be sure fuel tank is filled with correct fuel.
2	X	X					Heater assembly	Inspect for proper installation.
3	X	X					Installation	Be sure fumes are piped outside if heater is to be operated in a building or tent.
4	X						Combustion chamber	Inspect for broken welds and holes. Check combustion chamber to be sure there is no unburned fuel in it.
5	X						Fuel	Inspect for leaks or spilled fuel.
6	X						Water level	Check water level
7	X	X					Vent plug	Inspect control
8		X					Fuel valve	Adjust fuel flow
9			X	X	X		Heat body	Inspect for clean condition.
10				X	X		Burner	Inspect and service.

cracks, or breaks; if the burner is unserviceable, replace it.

Remove heater pipes and clean soot from the pipe sections. Wash the exterior of the pipe sections with a brush and hot water. Dry pipe sections thoroughly. Check the pipe sections for holes, dents, and excessive rusting. Replace the pipe sections as required. Check the vent plug gasket for deterioration. Remember, do NOT remove the vent plug from the tank.

TROUBLESHOOTING

Some of the malfunctions that may occur in an immersion heater are listed in table 9-7. Each malfunction listed has corresponding columns with the probable cause and suggested corrective action.

SAFETY PRECAUTIONS

This section contains safety information for operators and users of immersion heaters.

1. Do NOT fill fuel tanks indoors; spillage creates a hazardous condition.
2. Wipe up all spilled fuel and be sure that the fuel valve end of the tank is free of fuel and dry.
3. Ensure the heater installation is complete and meets requirements.
4. Do NOT operate the heater in a totally confined area. Sufficient ventilation to eliminate the accumulation of carbon monoxide fumes must be available.
5. Inspect the fuel container and lines for leaks. Repair leaks before lighting the heater.
6. Keep fuel outside the tent. Never store spare cans of fuel in the tent.
7. Keep a fire extinguisher available; all personnel should be instructed in its use.
8. Do NOT pour gasoline or oil on the fire during operation.
9. Do NOT operate the stove at full blast even in extremely cold weather. An overheated heater pipe can ignite tents.

REFERENCES

Building Maintenance, Plumbing, Heating, and Ventilation, NAVFAC MO-114, Department of the Navy, Naval Facilities Engineering Command, Alexandria, Va., 1982.

Heating, Ventilating, Air Conditioning, and Dehumidifying Systems, NAVFAC Design Manual 3.3, Department of the Navy, Naval Facilities Engineering Command, Alexandria, Va., 1980.

Heating, Ventilating, Air Conditioning, and Sheet Metal Work, TM 5-745, Department of the Army, Washington, D.C., 1968.

Table 9-7.—Troubleshooting the Immersion Heater

MALFUNCTION	PROBABLE CAUSE	CORRECTIVE ACTION
1. Heater fails to start	*a.* Insufficient preheating of flue.	*a.* Repeat preheating. Leave lighter in flue compartment until heater starts.
	b. Vent plug closed.	*b.* Open vent plug.
	c. Fuel tank empty.	*c.* Remove and fill tank.
	d. Water present in combustion chamber.	*d.* Stop operation and clear water from combustion chamber.
2. Burner goes out	*a.* Fuel tank empty.	*a.* Remove and fill tank.
	b. Vent plug closed or clogged.	*b.* Open vent plug and be sure it is free of obstruction.
	c. Water present in combustion chamber.	*c.* Stop operation and clear water from combustion chamber.
	d. Fuel rate too slow.	*d.* Open fuel valve.
	e. Flame blown out.	*e.* Shield heater from wind.
3. Heater smokes	*a.* Fuel rate too fast	*a.* Close fuel valve slightly.
	b. Stack is too short	*b.* Be sure to use at least four sections of pipe.

CHAPTER 10

REFRIGERATION AND AIR CONDITIONING

Learning Objective: Identify the stages of theory and the principles involved in heat transfer, and select the various components and arrange them according to their application in refrigeration and air-conditioning systems.

In civilian life, refrigerators and iceboxes are used to keep food from spoiling. In the Navy, where very large quantities of food must be stored, refrigeration systems for good storage warehouses are required. Refrigerated spaces are also used to store various items other than food. For instance, some medicines require refrigeration to prevent spoiling. Penicillin, used to fight infections, will go bad in a short time unless kept in a cool place. And blood, often needed to save lives, must be kept refrigerated, or else it, too, will become useless. From these examples you can easily see the importance of refrigeration in military, as well as civilian, life.

The installation, adjustment, and repair of refrigeration equipment are primary responsibilities of the Utilitiesman's rating. To perform these and the related duties required of a refrigeration mechanic, you need to understand the principles and theory of refrigeration. The time and effort that you spend in learning these basics will be amply rewarded by your increased efficiency in performing your refrigeration duties.

REFRIGERATION DEFINED

Refrigeration is the process of removing heat from an area or a substance and is usually done by an artificial means of lowering the temperature, such as the use of ice or mechanical refrigeration.

Mechanical refrigeration is defined as a mechanical system or apparatus so designed and constructed that, through its function, heat is transferred from one substance to another.

HEAT

Since refrigeration deals entirely with the removal or transfer of heat, some knowledge of the nature and effects of heat is necessary for a clear understanding of the subject.

NATURE OF HEAT

Heat is a form of energy contained to some extent in every substance on earth. All known elements are made up of very small particles known as atoms which, when joined together, form molecules. These molecules are particular to the form they represent. For example, carbon and hydrogen in certain combinations form sugar and in others form alcohol.

Molecules are in constant motion. Heat is a form of molecular energy that results from the motion of these molecules. The temperature of the molecules dictates to a degree the molecular activity within a substance. For this reason, substances exist in three different states or forms: solid, liquid, and gas. Water, for example, may exist in any one of these states. As ice, it is a solid; as water, it is a liquid; and as steam, it is a gas (vapor).

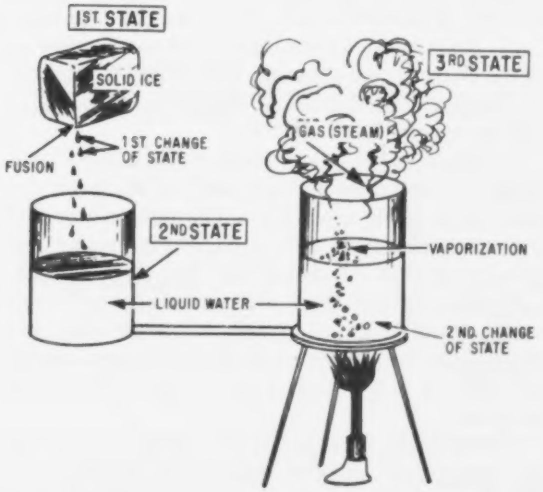
When heat is added to a substance, the rate of molecular motion increases causing the substance to change from a solid to a liquid, and then to a gas (vapor). For example, in a cube of ice, molecular motion is slow, but as heat is added, molecular activity increases, changing the solid "ice" to a liquid "water." (See fig. 10-1.) Further application of heat forces the molecules to greater separation and speeds up their motion so that the water changes into steam. The steam formed no longer has a definite volume, such as a solid or liquid has, but expands and fills whatever space is provided for it. Therefore, the molecular action in a substance is extremely active in the vapor state, while comparatively slow in the liquid state, and very slow in the solid state.

Heat cannot be destroyed or lost. However, it can be transferred from one body or substance to another, or to another form of energy. Since heat is not itself a substance, it can best be considered in relation to its effect on substances or bodies. When a body or substance is stated to be cold, the heat that it contains is less concentrated or less intense than the heat in some warmer body used for comparison.

UNITS OF HEAT

In the theory of heat, the speed of the molecules indicates the temperature or intensity of heat, while the number of molecules of a substance indicates the quantity of heat.

The intensity and quantity of heat may be explained in the following simple way. The water in a quart jar and in a 10-gallon container may have the same intensity or temperature, but the quantity of heat required to raise these amounts of water to a higher uniform temperature (from their present uniform temperature) will differ greatly. The 10 gallons of water will absorb a greater amount of heat than the quart jar of water.



54.144

Figure 10-1.—The three states of matter.

The amount of heat added to, or subtracted from, a body can best be measured by the rise or fall in temperature of a known weight of a substance. The standard unit of heat measure is the amount of heat necessary to raise the temperature of 1 pound of water 1 °F at sea level when water temperature is between 32 °F and 212 °F. Conversely, it is also the amount of heat that must be extracted to lower by 1 °F the temperature of a pound of water between the same temperature limits. This unit of heat is called a British thermal unit (Btu). As the metric system becomes more widely used, another unit of heat measurement will become more common. This is the calorie and is the amount of heat required to raise one gram of water 1 ° Celsius.

Suppose that the temperature of 2 pounds of water was raised from 35 °F to 165 °F. To find the number of Btu required to increase the temperature, subtract 35 from 165. This equals 130 ° temperature rise for 1 pound of water. Since 2 pounds of water were heated, multiply 130 by 2, which equals 260 Btu required to raise 2 pounds of water from 35 °F to 165 °F.

MEASUREMENT OF HEAT

The usual means for measuring temperature is a thermometer. It measures the degree or intensity of heat and usually consists of a glass tube with a bulb at the lower portion of the tube that contains mercury, colored alcohol, or a volatile liquid. The nature of these liquids causes them to rise or fall uniformly in the hollow tube with each degree of temperature change. Thermometers are used to calibrate the controls of refrigeration. The two most common thermometer scales are the Fahrenheit and the Celsius.

On the Fahrenheit scale, there is a difference of 180 ° between the freezing point (32 °) and the boiling point (212 °) of water. On the Celsius scale, you have only 100 ° of difference between the same points (0 freezing and 100 boiling point).

Of course, a Celsius reading can be converted to a Farenheit reading, and vice versa. To change a Celsius reading to a Fahrenheit reading, multiply the Celsius reading by 1.8 and add 32 °. This can be expressed in terms of the following formula:

$$F = (C \times 1.8) + 32$$

To change a Fahrenheit reading to a Celsius reading, subtract 32 from the Fahrenheit reading and then divide by 1.8. The formula which applies here is

$$C = \frac{(F - 32)}{1.8}$$

TRANSFER OF HEAT

Heat flows from bodies of higher temperature to bodies of lower temperature in the same manner that water flows down a hill, and like water, it can be raised again to a higher level so that it may repeat its cycle.

When two substances of different temperature are brought in contact with each other, heat will immediately flow from the warmer substance to the colder substance. The greater the difference in temperature between the two substances, the faster the heat flow. As the temperature of substances tends to equalize, the flow of heat slows and stops completely when the temperatures are equalized. This characteristic of heat is used in refrigeration. The heat of the air, of the lining of the refrigerator, and of the food to be preserved is transferred to a colder substance called the refrigerant.

Heat, as a form of energy, cannot be destroyed. Bear in mind, though, that it can be transferred from one substance to another. Three methods by which heat may be transferred from a warmer substance to a colder substance are conduction, convection, and radiation.

CONDUCTION is the method by which heat flows from a warmer substance to a colder substance when there is physical contact between them. It also is the method by which heat flows within solids. A cold metal bar placed against red-hot metal soon becomes too hot to hold at the end farthest from the source of heat, illustrating heat transfer from body to body and heat flow within a solid. Refrigeration makes use of this method of heat transfer in the cooling process; for example, of canned foods. Here, the heat from the food is transferred by conduction to the can first, and the heat of the can is transferred by conduction to the surrounding cold air in the refrigerator.

CONVECTION means the transfer of heat within a fluid (liquid or gas) body. Here the flow of heat is caused by the natural motion of the heated substance itself whether liquid or gas. Take a pan of boiling water as an example. When heated, the water becomes lighter and bubbles to the top of the pan, and the cooler water on top, being heavier, falls to the bottom of the pan to be heated by conduction. This movement of water by convection provides for more uniform heating of the pan of water. In refrigeration, convection explains how the heat from the air around the canned food is removed. The cooling device in a refrigerator is usually located in the upper portion of the space to be cooled, and when the air surrounding it becomes cooled (by conduction), it becomes heavier and falls to the bottom of the space. The air there has been warmed by the canned food and, being lighter, rises to the cooling device.

In RADIATION, no material substance acts as a heat carrier. A person sitting near a hot stove is warmed by radiant heat even though the air between the person and the stove may remain cold. Similarily, radiant heat from the sun warms the earth without warming the space through which it passes. Radiant heat may pass through a transparent substance without warming it and is stopped or absorbed by an opaque substance. Radiant heat travels only in a straight line from its source and can best be reflected from a polished surface and absorbed by a dull, black surface.

SPECIFIC HEAT

Specific heat is a term used to express the ratio between the quantity of heat required to change the temperature of 1 pound of any substance 1 °F, as compared to the quantity of heat required to change 1 pound of water 1 °F. The specific heat is equal to the number of Btu required to raise the temperature of 1 pound of a substance 1 °F. For example, the specific heat of milk is .92, which means that 92 Btu will be needed to raise 100 pounds of milk 1 °F. The specific heat of water is 1, by adoption as a standard, and the specific heat of another substance (solid, liquid, or gas) is determined experimentally by comparing it to water. Specific heat also expresses the heat-holding capacity of a substance compared to that of water. Table 10-1 gives the specific heat of a few common substances.

Remember that about .5 Btu of heat is required to raise 1 pound of ice 1 °F when the temperature is below 32 °F; and about .5 Btu of heat is required to raise 1 pound of steam 1 °F above the temperature of 212 °F.

SENSIBLE HEAT

Heat that is added to, or subtracted from, a substance that changes its temperature but not its physical state is called "sensible heat." It is the heat that can be indicated on a thermometer. This is the heat which human senses also can react to, at least within certain ranges. For example, if a person puts his finger into a cup of water, the senses readily tell that person whether it is cold, cool, tepid, hot, or very hot. Sensible heat is applied to a solid (as ice), a liquid (as water), or a vapor/gas (as steam) as indicated on a thermometer. The term *sensible heat* does not apply to the process of conversion from one physical state to another.

LATENT HEAT

Latent heat, or hidden heat, is the term used for the heat absorbed or given off by a substance while it is changing its physical state. When a substance is changing its physical state, the heat absorbed or given off does NOT cause a temperature change in the substance. In other words, *sensible heat* is the term for heat that affects the temperature of things; *latent heat* is the term for heat that affects the physical state of things.

To understand the concept of latent heat, you must realize that many substances may exist as solids, as liquids, or as gases, depending primarily upon the temperatures and pressure to which they are subjected. When the pressure is kept constant, the physical state of a substance depends upon its temperature. To change a solid to a liquid, or a liquid to a gas, ADD HEAT; to change a gas to a liquid, or a liquid to a solid, REMOVE heat. The heat required to change the physical state of the substance, WITHOUT any change in temperature, is termed *latent heat*. You might say that latent heat is the price, in terms of heat energy, that must be paid for a change of state.

Suppose you take an uncovered pan of cold water and put it over a burner. The sensible heat of the water increases and so does the temperature. As you continue adding heat to the water in the pan, the temperature of the water continues to rise until it reaches 212 °F. What is happening? The water is now absorbing its latent heat of vaporization and is changing from a liquid to a vapor. The heat required to change a liquid to a gas (or, on the other hand, the heat that must be removed from a gas to condense it to a liquid) without any change in temperature is known as the LATENT HEAT OF VAPORIZATION.

Now suppose you take another pan of cold water and put it in a place where the temperature is below 32 °F. The water gradually loses heat to its surroundings, and the temperature of the water

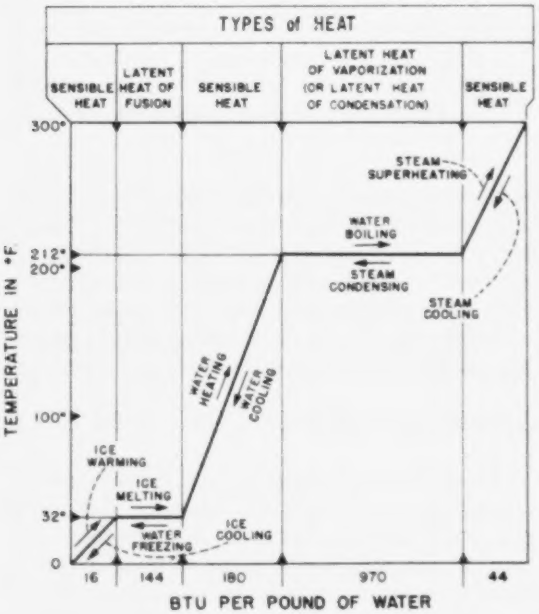
Table 10-1.—Specific Heat of Some Common Substances

Solids		Liquids		Vapors	
Ice	0.504	Water	1.000	Steam	0.48
Iron	.130	Grain Alcohol	.648	Air	.24
Copper	.095	Oil	.45	Hydrogen	3.4
Lead	.031	Ammonia	1.1	Ammonia	.523
Glass	.194	Isobutane	.5	Isobutane	.4
Brick	.2	Methyl Chloride	.38	Methyl Chloride	.24

drops to 32 °F until all the water has changed to ice. While the water is changing to ice, however, it is still losing heat to its surroundings. The heat that must be removed from a substance to change it from a liquid to a solid (or, on the other hand, the heat which must be added to a solid to change it to a liquid) without change of temperature is called the LATENT HEAT OF FUSION.

Note that the amount of heat required to cause a change of state (or, on the other hand, the amount of heat given off when a substance changes its state) varies according to the pressure under which the process takes place.

Figure 10-2 shows the relationship between sensible heat and latent heat for one substance, water, at atmospheric pressure. To raise the temperature of 1 pound of ice from 0 °F to 32 °F, you must add only 16 Btu. To change the pound of ice at 32 °F to a pound of water at 32 °F, you must add 144 Btu (the latent heat of fusion). There is no change in temperature while the ice is melting. After all the ice is melted, however, the temperature of the water is raised when more heat is applied. When 180 Btu (1 Btu for each degree of temperature increase between 32 °F and 212 °F) are added, the water boils. To change a pound of water at 212 °F to a pound of steam at 212 °F, you must add 970 Btu (the latent heat of vaporization). After all the water is converted to steam at 212 °F, the application of additional heat causes a rise in the temperature of the steam. When you add 44 Btu to the steam at 212 °F the steam is superheated to 300 °F.



38.1

Figure 10-2.—Relationship between temperature and the amount of heat required per pound (for water at atmospheric pressure).

TOTAL HEAT

Total heat is the sum of sensible and latent heat. Since measurements of the total heat in a certain weight of a substance cannot be started at absolute zero, a temperature is adopted at which it is assumed that there is no heat; and tables of data are constructed on that basis for practical use. Data tables giving the heat content of the most commonly used refrigerants start at 40 °F below zero as the assumed point of no heat; tables for water and steam start at 32 °F above zero. Tables of data usually contain a notation showing the starting point for heat content measurement.

DAY-TON OF REFRIGERATION

A day-ton of refrigeration (sometimes incorrectly called simply a ton of refrigeration) is the amount of refrigeration produced by melting one ton of ice at a temperature of 32 °F in 24 hours. It is often used to express the amount of cooling produced by a refrigerator or air-conditioner, as, for example, a 1-ton air-conditioner can remove as much heat in 24 hours as 1 ton of 32 °F-ice that melts and becomes water at 32 °F. It is a rate of removing heat rather than a quantity of heat. A rate can be converted to Btu per day, hour, or minute.

To find the rate (in Btu per day), multiply 2,000 (the number of pounds of ice in 1 ton) by Btu (the latent heat of fusion per pound). You should note that 1 day-ton of refrigeration equals 288,000 Btu per day.

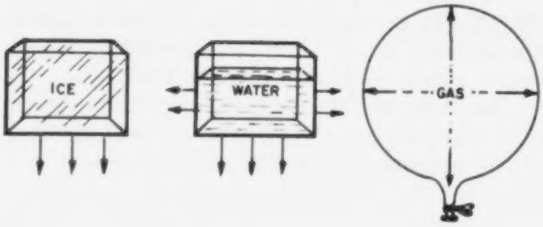
To calculate the rate per hour, divide the 288,000 Btu per day by 24. The answer is 12,000 Btu per hour. So, a "1-ton" air-conditioner would have a rating of 12,000 Btu per hour.

Similarly, to find the rate per minute, divide 12,000 Btu per hour by 60. Therefore, 1 day-ton of refrigeration equals 200 Btu per minute.

PRESSURE

"Pressure" is defined as a force per unit area. It is usually measured in pounds per square inch (psi). Pressure may be in one direction, several directions, or in all directions, as shown in figure 10-3. The ice (a solid) exerts pressure downward only. The water (a fluid) exerts pressure on all wetted surfaces of the container. Gases exert pressure on all inside surfaces of their containers.

Pressure is usually measured on gauges that have one of two different scales. One scale is read as so many pounds per square inch gauge (psig) and indicates the pressure above the atmospheric pressure surrounding the gauge. The other type of scale is read as so many pounds per square inch absolute (psia) and indicates the pressure above absolute zero pressure (a perfect vacuum).

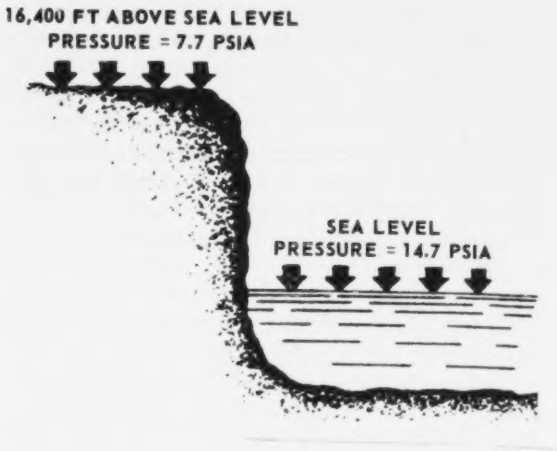


54.147

Figure 10-3.—Exertion of pressures.

ATMOSPHERIC PRESSURE

Atmospheric pressure is the pressure of the weight of the air above a point on, above, or under the earth. At sea level, it is 14.7 psia, as shown in figure 10-4. As one ascends, the atmospheric pressure decreases about 1.0 psi for every 2,343 feet. However, below sea level in excavations and depressions, atmospheric pressure increases. Pressures underwater differ from those under air only because the weight of the water above must be added to the pressure of the air.



54.148

Figure 10-4.—Atmospheric pressure.

SCALE RELATIONSHIPS

A definite relationship exists between the readings of a gauge calibrated in psig and another, calibrated in psia. As shown in figure 10-5, when the psig gauge reads 0, the psia gauge reads the atmospheric pressure (14.7 psia at sea level). In other words, the psia reading equals the psig reading plus the atmospheric pressure (7.7 psia at 16,400 feet). Similarly, a psig reading equals the psia reading minus the atmospheric pressure.

ABSOLUTE SCALE (PSIA)	GAUGE SCALE (PSIG)	INCHES OF MERCURY	INCHES OF WATER
44.7	30	NOT USED	NOT USED
24.7	10	NOT USED	NOT USED
14.7	0	0	0
0	NOT USED	-30	-408

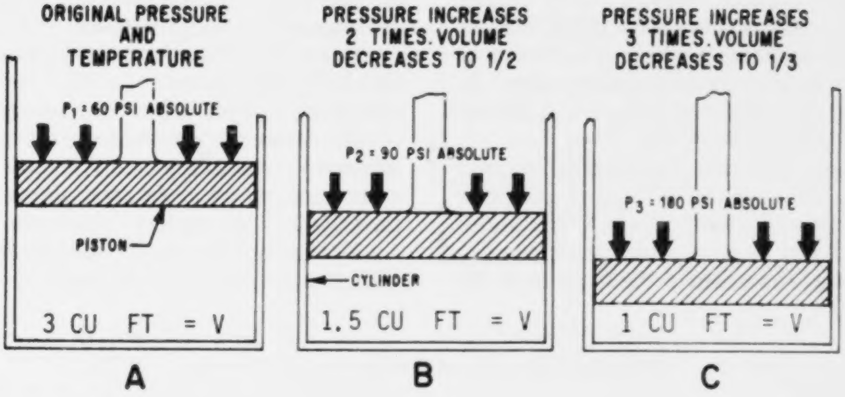
54.336

Figure 10-5.—Pressure relationship.

For pressure less than the atmospheric pressure (partial vacuums), a measuring device with a scale reading in inches of mercury (Hg) or in inches of water (H_2O) is used. As can be seen from figure 10-5, a perfect vacuum is equal to −30 inches of mercury or −408 inches of water. In refrigeration work, pressures above atmospheric are measured in pounds per square inch, and pressures below atmospheric are measured in inches of mercury.

EFFECTS OF PRESSURE ON GASES

The exertion of pressure on a substance with a constant temperature decreases its volume in proportion to the increase of pressure. For example, suppose that a given amount of gas is placed in a cylinder that is sealed on one end and has a movable piston on the other end. When 60 psi of absolute pressure is exerted on the piston, as shown in view A of figure 10-6, the volume of the gas is compressed to 3 cubic feet. When 90 psi of absolute pressure is exerted on the piston,

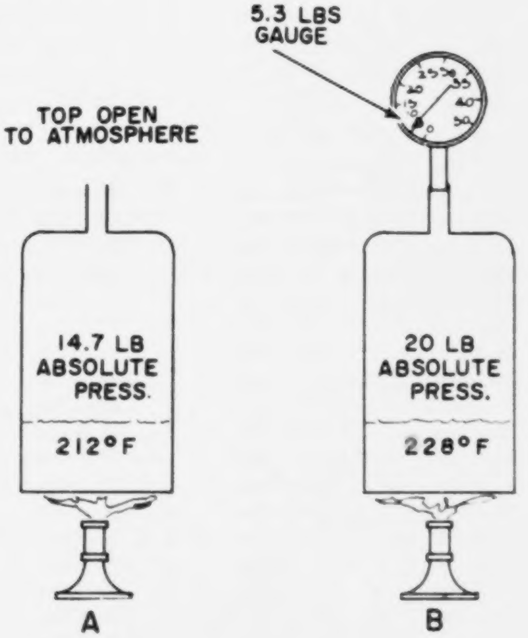

ORIGINAL PRESSURE AND TEMPERATURE
PRESSURE INCREASES 2 TIMES. VOLUME DECREASES TO 1/2
PRESSURE INCREASES 3 TIMES. VOLUME DECREASES TO 1/3
P1 = 60 PSI ABSOLUTE
P2 = 90 PSI ABSOLUTE
P3 = 180 PSI ABSOLUTE
PISTON
CYLINDER
3 CU FT = V
1.5 CU FT = V
1 CU FT = V
A
B
C

54.150

Figure 10-6.—Pressure-volume relationship.

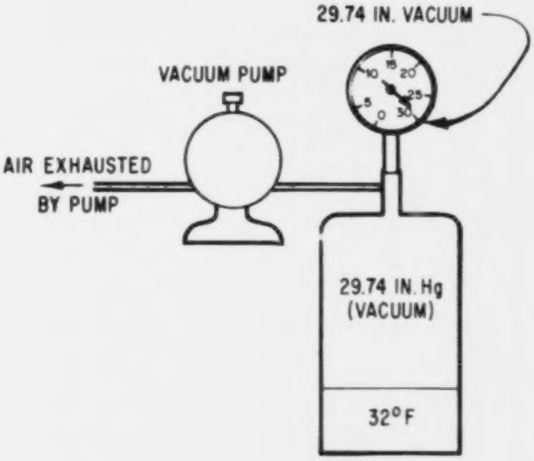
as shown in view B, the volume of the gas is compressed to 1.5 cubic feet. Finally, when 180 psi of absolute pressure is exerted on the piston, as shown in view C, the volume of the gas is compressed to 1 cubic foot. Thus, if a given amount of gas is confined in a container and subject to changes of pressure, its volume changes, so the product of volume multiplied by absolute pressure is always the same.

Pressure has a definite relationship to the boiling point of a substance. There is a definite temperature at which a liquid boils for every definite pressure exerted upon it. For instance, water boils at 212 °F at atmospheric pressure (14.7 psia), as shown in view A, figure 10-7. The same water boils at 228 °F if the pressure is raised 5.3 psig (20 psia), as illustrated in view B, figure 10-7. On the other hand, the same water boils at 32 °F in a partial vacuum of 29.74 inches of mercury (Hg), as shown in figure 10-8.


5.3 LBS GAUGE
TOP OPEN TO ATMOSPHERE
14.7 LB ABSOLUTE PRESS.
212°F
20 LB ABSOLUTE PRESS.
228°F
A
B

54.151

Figure 10-7.—A. Water boils at atmospheric pressure. B. Water boils at 20-psi absolute pressure.


29.74 IN. VACUUM
VACUUM PUMP
AIR EXHAUSTED BY PUMP
0
5
10
15
20
25
30
29.74 IN. Hg (VACUUM)
32°F

54.152

Figure 10-8.—Water boils quicker in a vacuum.

This effect of reduced pressure on the boiling temperature of refrigerants makes the operation of a refrigeration system possible. For instance, the pressure temperature relationship chart in table 10-2 gives the pressures for several different refrigerants.

In table 10-2, note that liquid sulfur dioxide (SO_2) at any given temperature requires a definite amount of pressure to keep it in a liquid state. When a cylinder of SO_2 is placed in a room at 20 °F and allowed to remain in the room until the temperature of the liquid is exactly 20 °F, the corresponding gauge pressure will be 2.5 psi.

When the same container is placed in a room that has a temperature of 55 °F, then the SO_2 has a pressure 22.4 psi. When the container is returned to the room with a temperature of 20 °F and allowed to remain there until it cools down to the exact temperature of the room, the pressure drops down to 2.5 psi again.

Thus, an increase in temperature of refrigerants results in an increase in pressure, and

Table 10-2.—Relation of Temperature and Pressure

TEMP. °F	R-22 $CHClF_2$	R-12 CCl_2F_2	SULFUR DIOXIDE SO_2	AMMONIA NH_3	METHYL CHLORIDE CH_3Cl
-40	0.6 lbs.	10.9 in.	23.5 in.	8.7 in.	15.9 in.
-35	2.7 lbs.	8.4 in.	22.4 in.	5.4 in.	13.8 in.
-30	4.9 lbs.	5.5 in.	21.1 in.	1.6 in.	11.5 in.
-25	7.5 lbs.	2.3 in.	19.6 in.	1.3 lbs.	8.9 in.
-20	10.2 lbs.	0.6 lbs.	17.9 in.	3.6 lbs.	6.1 in.
-15	13.3 lbs.	2.4 lbs.	16.1 in.	6.2 lbs.	2.9 in.
-10	16.6 lbs.	4.5 lbs.	13.9 in.	9.0 lbs.	0.3 lbs.
- 5	20.3 lbs.	6.8 lbs.	11.5 in.	12.2 lbs.	2.1 lbs.
0	24.1 lbs.	9.2 lbs.	8.9 in.	15.7 lbs.	4.2 lbs.
+ 5	28.4 lbs.	11.8 lbs.	5.9 in.	19.6 lbs.	6.5 lbs.
10	32.9 lbs.	14.7 lbs.	2.6 in.	23.8 lbs.	8.9 lbs.
15	38.5 lbs.	17.7 lbs.	0.5 lbs.	28.4 lbs.	11.6 lbs.
20	43.3 lbs.	21.1 lbs.	2.5 lbs.	33.5 lbs.	14.5 lbs.
25	49.1 lbs.	24.6 lbs.	4.6 lbs.	39.0 lbs.	17.6 lbs.
30	55.2 lbs.	28.5 lbs.	7.0 lbs.	45.0 lbs.	21.0 lbs.
35	61.8 lbs.	32.6 lbs.	9.6 lbs.	51.6 lbs.	24.6 lbs.
40	69.0 lbs.	37.0 lbs.	12.4 lbs.	58.6 lbs.	28.6 lbs.
45	76.7 lbs.	41.7 lbs.	15.5 lbs.	66.3 lbs.	32.8 lbs.
50	84.7 lbs.	46.7 lbs.	18.8 lbs.	74.5 lbs.	37.3 lbs.
55	93.3 lbs.	52.0 lbs.	22.4 lbs.	83.4 lbs.	42.1 lbs.
60	102.5 lbs.	57.7 lbs.	26.2 lbs.	92.9 lbs.	47.3 lbs.
65	112.3 lbs.	63.7 lbs.	30.4 lbs.	103.1 lbs.	52.8 lbs.
70	122.5 lbs.	70.1 lbs.	34.9 lbs.	114.1 lbs.	58.7 lbs.
75	133.4 lbs.	76.9 lbs.	39.8 lbs.	125.8 lbs.	65.0 lbs.
80	145.0 lbs.	84.1 lbs.	45.0 lbs.	138.3 lbs.	71.6 lbs.
85	157.2 lbs.	91.7 lbs.	50.6 lbs.	151.7 lbs.	78.6 lbs.
86	159.5 lbs.	93.2 lbs.	51.8 lbs.	154.5 lbs.	80.0 lbs.
90	170.1 lbs.	99.6 lbs.	56.6 lbs.	165.9 lbs.	86.0 lbs.
95	183.6 lbs.	108.1 lbs.	62.9 lbs.	181.1 lbs.	93.8 lbs.
100	197.9 lbs.	116.9 lbs.	69.8 lbs.	197.2 lbs.	102.0 lbs.
105	212.9 lbs.	126.2 lbs.	77.2 lbs.	214.2 lbs.	110.7 lbs.
110	228.7 lbs.	136.0 lbs.	85.1 lbs.	232.3 lbs.	119.8 lbs.
115	252.1 lbs.	146.5 lbs.	93.3 lbs.	251.5 lbs.	129.5 lbs.
120	262.6 lbs.	157.1 lbs.	101.8 lbs.	271.7 lbs.	139.5 lbs.

54.153

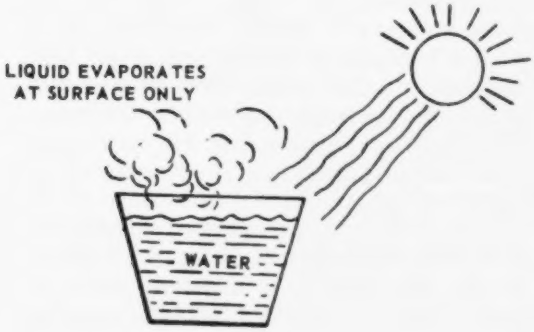
a decrease in temperature causes a decrease in pressure. By the same token, a decrease in pressure results in a corresponding decrease in temperature.

This means that as the pressure of a refrigerant is increased, so is the temperature at which the refrigerant boils. Thus, by regulating the pressure of the refrigerant, the temperature at which evaporation takes place and at which the latent heat of evaporation is used can be controlled.

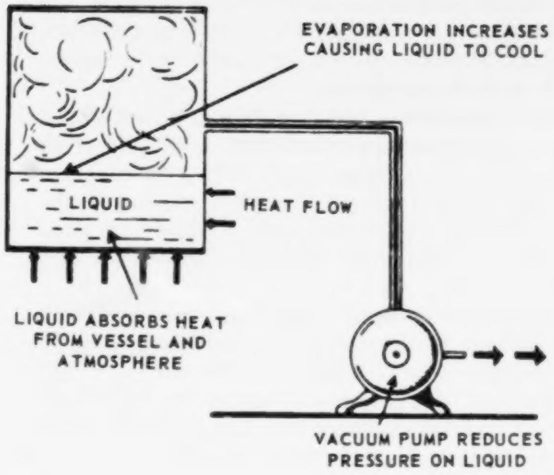
VAPORIZATION

Vaporization is the process of changing a liquid to vapor, either by evaporation or boiling. When a glass is filled with water, as shown in figure 10-9, and exposed to the rays of the sun for a day or two, you should note that the water level drops gradually. The loss of water is due to evaporation. Evaporation, in this case, takes place only at the surface of the liquid. It is gradual, but the evaporation of the water can be speeded up if additional heat is applied to it. In this case, the boiling of the water takes place throughout the interior of the liquid. Thus, the absorption of heat by a liquid causes it to boil and evaporate.

Vaporization can also be increased by reducing the pressure on the liquid, as shown in figure 10-10. Pressure reduction lowers the temperature at which the liquid boils and hastens its evaporation. When a liquid evaporates, it absorbs heat from warmer surrounding objects and cools them. Refrigeration by evaporation is based on this method. The liquid is allowed to expand under reduced pressure, vaporizing and extracting heat from the container (freezing compartment) as it changes from a liquid to a gas. After the gas is expanded (and heated), it is compressed, cooled, and condensed into a liquid again.


LIQUID EVAPORATES AT SURFACE ONLY
WATER

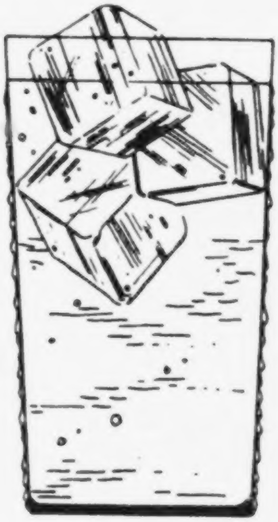
54.154
Figure 10-9.—Normal surface evaporation.


EVAPORATION INCREASES CAUSING LIQUID TO COOL
LIQUID
HEAT FLOW
LIQUID ABSORBS HEAT FROM VESSEL AND ATMOSPHERE
VACUUM PUMP REDUCES PRESSURE ON LIQUID

54.155
Figure 10-10.—Evaporation by pressure reduction.

CONDENSATION

Condensation is the process of changing a vapor into a liquid. For example, in figure 10-11,



54.156
Figure 10-11.—Condensation of moisture on a glass of cold water.

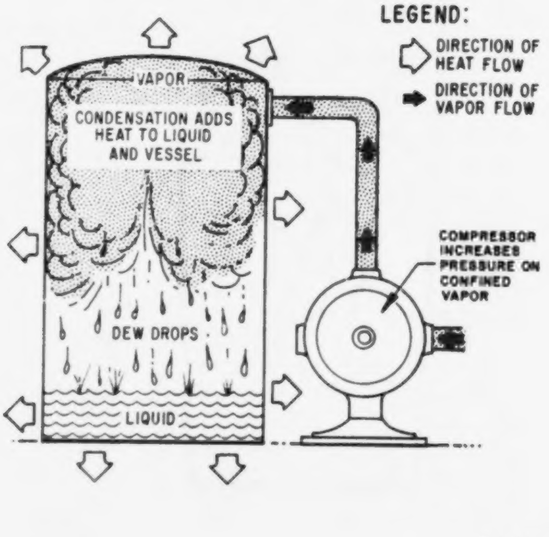
a warm atmosphere gives up heat to a cold glass of water, causing moisture to condense out of the air and form on the outside surface of the glass. Thus, the removal of heat from a vapor causes the vapor to condense.

An increase in pressure on a confined vapor also causes the vapor to change to a liquid. This fact is shown in figure 10-12. When the pressure on the vapor is increased by the compressor, the condensing vapor changes to a liquid and gives up heat to the cooler surrounding objects and atmosphere.

These conditions exist when the vaporized refrigerant is compressed by the compressor of a refrigeration system and forced into the condenser. The condenser removes the superheat, latent heat of vaporization, and in some cases, sensible heat from the refrigerant.

MECHANICAL REFRIGERATION SYSTEMS

Mechanical refrigeration systems are an arrangement of components in a system that puts the theory of gases discussed so far into practice to provide artificial cooling. To do this, you must provide (1) a metered supply of relatively cool liquid under pressure; (2) a device in the space to be cooled that operates at reduced pressure so that when the cool, pressurized liquid enters, it will expand, evaporate, and take heat from the space to be cooled; (3) a means of repressurizing (compressing) the vapor; and (4) a means of condensing it back into a liquid, removing its superheat, latent heat of vaporization, and some of its sensible heat.


LEGEND:
DIRECTION OF HEAT FLOW
DIRECTION OF VAPOR FLOW
VAPOR
CONDENSATION ADDS HEAT TO LIQUID AND VESSEL
DEW DROPS
LIQUID
COMPRESSOR INCREASES PRESSURE ON CONFINED VAPOR

54.157

Figure 10-12.—Pressure causes a vapor to condense.

Every mechanical refrigeration system operates at two definite pressure levels. The dividing line is shown in figure 10-13. This line passes through the discharge valves of the compressor on one end and through the orifice of the metering device or expansion valve on the other.

The high-pressure side of a refrigeration system comprises all the components that operate at or above condensing pressure. These components are the discharge side of the compressor, the condenser, the receiver, and all interconnected tubing up to the metering device or expansion valve.

The low-pressure side of a refrigeration system consists of all the components that operate at or below evaporating pressure. These components comprise the low-pressure side of the expansion valve, the evaporator, and all the interconnecting tubing up to and including the low side of the compressor.

Refrigeration mechanics call the pressure on the high side "head pressure," "discharge pressure," or "high side pressure." On the low side, the pressure is called "suction pressure," or "low side pressure."

The refrigeration cycle of a mechanical refrigeration system may be explained with figure 10-13.

The pumping action of the compressor (1) draws vapor from the evaporator (2). This action reduces the pressure in the evaporator causing the liquid particles to evaporate. As the liquid particles evaporate, this cools the evaporator. Both the liquid and vapor refrigerant tend to extract heat from the warmer objects in the insulated refrigerator cabinet. The ability of the liquid as it vaporizes to absorb heat is very high in comparison to that of the vapor. As the liquid refrigerant is vaporized, the low-pressure vapor is drawn into the suction line by the suction action of the compressor (1). The evaporation of the liquid refrigerant would soon remove all the refrigerant from the evaporator if it were not replaced. The replacement of the liquid refrigerant is usually controlled by a metering device or expansion valve (3). This device acts as a restrictor to the flow of the liquid refrigerant in the liquid line. Its function is to change the high pressure, subcooled liquid refrigerant to low pressure, low-temperature liquid particles, which will continue the cycle by absorbing heat.

The refrigerant low-pressure vapor drawn from the evaporator by the compressor through the suction line, in turn, is compressed by the compressor to a high-pressure vapor which is forced into the condenser (4). In the condenser, the high-pressure vapor condenses to a liquid under high pressure and gives up heat to the condenser. The heat is removed from the condenser by the cooling medium of air or water. The condensed liquid refrigerant is then forced into the liquid receiver (5) and through the liquid line to the expansion valve by pressure created by the compressor, making a complete cycle.

Although the receiver is indicated as part of the refrigeration system in figure 10-13, it is not a vital component. The omission of the receiver, however, requires exactly the proper amount of refrigerant in the system. The refrigerant charge in systems without receivers is to be considered critical, as any variations in quantity affects the operating efficiency of the unit.

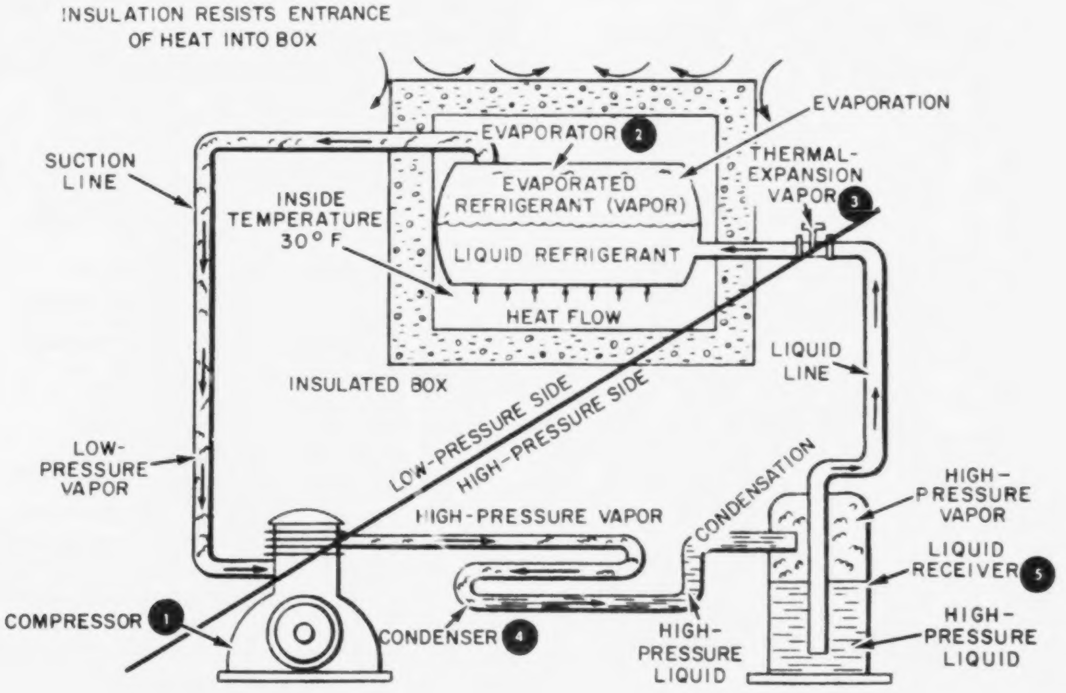
The refrigeration cycle of any refrigeration system must be clearly understood by a mechanic before repairing the system. The Utilitiesman 3 must understand how a refrigerant should be controlled, so it will absorb heat as it passes through the evaporator and give up heat as it passes through the condenser. Knowing how a refrigerant works makes it easier to detect faults in a refrigeration system.

COMPONENTS OF MECHANICAL SYSTEMS

The refrigeration system consists of four basic parts: the compressor, condenser, evaporator, and control devices. Information on these parts is given below.

COMPRESSORS

Refrigeration compressors have but one purpose: to withdraw the heat-laden refrigerant vapor from the evaporator and compress the gas to a pressure that will liquefy in the condenser. The designs of compressors vary depending upon the application and type of refrigerant. There are


INSULATION RESISTS ENTRANCE OF HEAT INTO BOX
EVAPORATION
EVAPORATOR ❷
SUCTION LINE
INSIDE TEMPERATURE 30° F
EVAPORATED REFRIGERANT (VAPOR)
THERMAL-EXPANSION VAPOR ❸
LIQUID REFRIGERANT
HEAT FLOW
LIQUID LINE
INSULATED BOX
LOW-PRESSURE SIDE
HIGH-PRESSURE SIDE
LOW-PRESSURE VAPOR
CONDENSATION
HIGH-PRESSURE VAPOR
HIGH-PRESSURE VAPOR
LIQUID RECEIVER ❺
COMPRESSOR ❶
CONDENSER ❹
HIGH-PRESSURE LIQUID
HIGH-PRESSURE LIQUID

47.90

Figure 10-13.—Refrigeration cycle.

three types of compressors classified according to the principle of operation: reciprocating, rotary, and centrifugal.

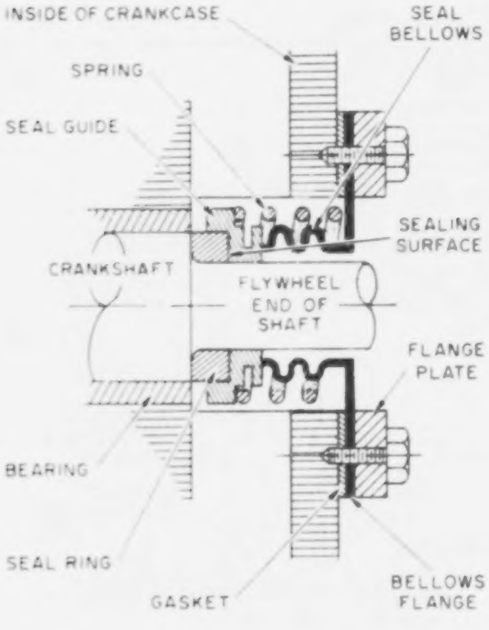
You may recall that material on compressors was presented in chapter 5 of this text. They will not be explained further here except to discuss the special methods used to seal compressors to prevent the escape of refrigerant. Many refrigerator compressors have components besides those normally found on compressors, such as unloaders, oil pumps, mufflers, and so on. These devices are too complicated to explain here. Before repairing any compressor, check the manufacturer's manual for an explanation of their operation, adjustment, and repair.

A leakproof seal must be maintained where the crankshaft extends out of the crankcase of an open type of compressor. The seal must be designed to hold the pressure developed inside of the compressor. It must prevent the refrigerant and compressor oil from leaking out and prevent air and moisture from entering the compressor. For these purposes two different types of seals are commonly used: the stationary bellows seal and the rotating bellows seal.

An internal stationary bellows crankshaft seal, shown in figure 10-14, consists of a corrugated thin brass tube (seal bellows) fastened to a bronze ring (seal guide) at one end and to the flange plate at the other end. The flange plate is bolted to the crankcase with a gasket between the two units. A spring presses the seal guide mounted on the other end of the bellows against a seal ring positioned against the shoulder of the crankshaft. As the pressure builds up in the crankcase, the bellows tend to lengthen, causing additional force to press the seal guide against the seal ring. Oil from the crankcase lubricates the surfaces of the seal guide and seal ring. The seal guide is accurately lapped to the seal ring, so the two surfaces form a gastight seal whether the compressor is running or is idle.

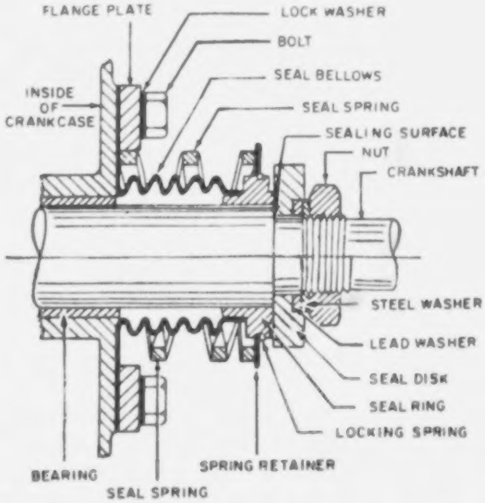
An external stationary bellows crankshaft seal is shown in figure 10-15. This seal is similar to the internal bellows seal, except that it is positioned on the outside of the crankcase.

A diagram of an external rotating bellows crankcase seal is shown in figure 10-16. This type of seal turns with the crankshaft. The rotating bellows seal also consists of a corrugated thin brass tube (seal bellows) with a seal ring fastened to one end and a seal flange fastened to the other. A seal spring is enclosed within the bellows. The complete bellows assembly slips on the end of the crankshaft and is held in place by a nut. The seal ring that is the inner portion of the bellows is positioned against a nonrotating seal fastened


INSIDE OF CRANKCASE
SEAL BELLOWS
SPRING
SEAL GUIDE
SEALING SURFACE
CRANKSHAFT
FLYWHEEL END OF SHAFT
FLANGE PLATE
BEARING
SEAL RING
GASKET
BELLOWS FLANGE

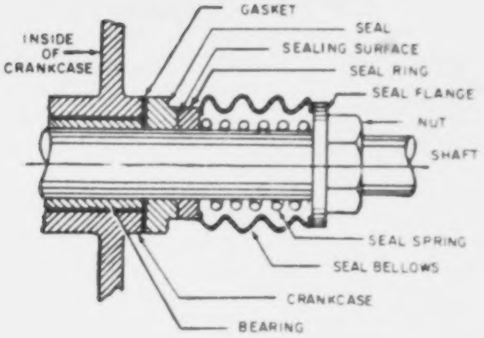
54.159

Figure 10-14.—An internal stationary bellows crankshaft seal.

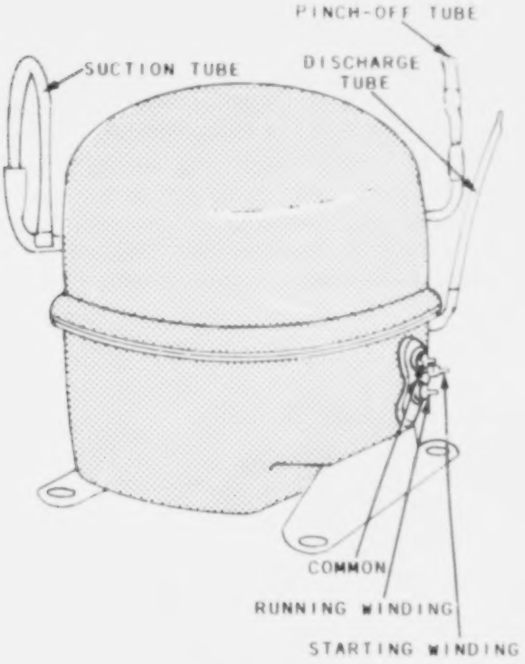

FLANGE PLATE
LOCK WASHER
BOLT
SEAL BELLOWS
INSIDE OF CRANKCASE
SEAL SPRING
SEALING SURFACE
NUT
CRANKSHAFT
STEEL WASHER
LEAD WASHER
SEAL DISK
SEAL RING
LOCKING SPRING
SPRING RETAINER
BEARING
SEAL SPRING

54.160

Figure 10-15.—An external stationary bellows crankshaft seal.


INSIDE OF CRANKCASE
GASKET
SEAL
SEALING SURFACE
SEAL RING
SEAL FLANGE
NUT
SHAFT
SEAL SPRING
SEAL BELLOWS
CRANKCASE
BEARING

54.161
Figure 10-16.—An external rotating bellows crankcase seal.


PINCH-OFF TUBE
SUCTION TUBE
DISCHARGE TUBE
COMMON
RUNNING WINDING
STARTING WINDING

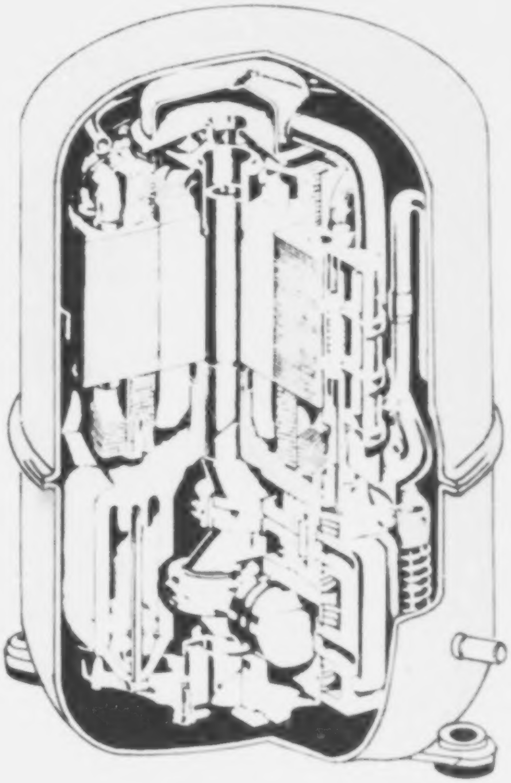
168.12
Figure 10-17.—Hermetic compressor.

directly to the crankcase. The surfaces of the seal and seal ring are accurately lapped, so two surfaces form a gastight seal.

During operation, the complete bellows assembly rotates with the shaft, causing the seal ring to rotate against the stationary seal. The pressure of the seal spring holds the seal ring against the seal. The expansion of the bellows caused by the pressure from the crankcase also exerts pressure on the seal ring. Because of this design, a double pressure is exerted against the seal ring to provide a gastight seal between it and the stationary seal.

HERMETICALLY SEALED COMPRESSORS

The problem of prevention of leaks at the crankshaft seals of the open type of refrigeration compressors can be eliminated by the use of hermetically sealed compressors. In the design of open type of compressors, the shaft of an external electric motor is coupled to the compressor crankshaft; whereas, in the hermetically sealed unit, the electric motor and compressor are both in the same airtight (hermetic) housing and share the same shaft. Figure 10-17 shows a hermetically sealed unit. Note that, after assembly, the two halves of the case are welded together to form an airtight cover. Figure 10-18 shows an accessible type of



87.429
Figure 10-18.—Hermetic compressor motor.

hermetically sealed unit. The compressor, in this case, is a double-piston reciprocating type with a crankshaft common to the electric motor. Other compressors may be of the centrifugal or rotary types. Cooling and lubrication are provided by the circulating oil and the movement of the refrigerant vapor throughout the case.

The advantages of the hermetically sealed unit (elimination of the need for pulleys, belts, and other coupling methods and the elimination of a source of refrigerant leaks) are offset somewhat by the inaccessibility for repair and generally lower capacity.

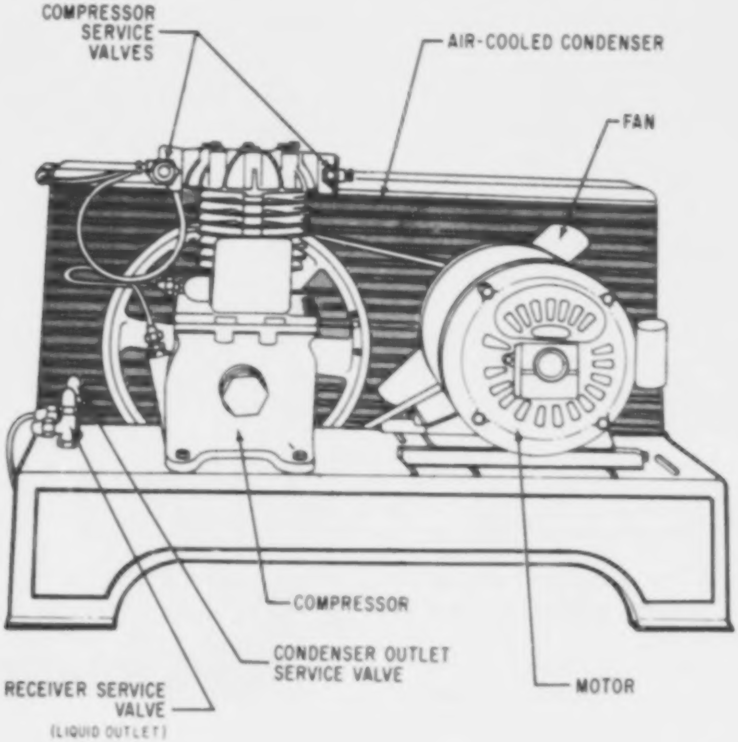
CONDENSERS

The condenser in a refrigeration system removes and dissipates heat from the compressed vapor to the surrounding air or water to condense the refrigerant vapor to a liquid. The liquid refrigerant then falls by gravity to a receiver (usually located below the condenser), where it is stored, and available for future use in the cycle.

There are three types of condensers: air-cooled, circulating-water-cooled, and evaporative condensers. The first two types are the most common, but evaporative types are used where low-quality water and its disposal make the use of circulating-water-cooled types impractical.

Air-cooled Condenser

The construction of air-cooled condensers makes use of several layers of small tubing formed into flat coils. The external surface of this tubing is provided with fins to ease the transfer of heat from the condensing refrigerant inside the tubes to the air circulated through the condenser core around the external surface of the tubes. (See fig. 10-19.) Condensation takes place as the refrigerant flows through the tubing, and the liquid refrigerant is discharged from the lower ends of the tubing coils to a liquid receiver on the condensing unit assembly.



54.288

Figure 10-19.—Air-cooled condenser mounted on compressor unit.

Water-cooled Condenser

Water-cooled condensers are of the multipass shell and tube type, with circulating water flowing through the tubes. The refrigerant vapor is admitted to the shell and condensed on the outer surfaces of the tubes. (See fig. 10-20.)

The condenser is constructed with a tube sheet brazed to each end of a shell. Copper-nickel tubes are inserted through drilled openings in the tube sheet and are expanded or rolled into the tube sheet to make a gastight seal. Headers, or water boxes, are bolted to the tube sheet to complete the water side of the condenser. Zinc wasting bars are installed in the water boxes to minimize electrolytic corrosion of the condenser parts.

A purge connection with a valve is at the top side of the condenser shell to allow manual release of any accumulated air in the refrigerant circuit.

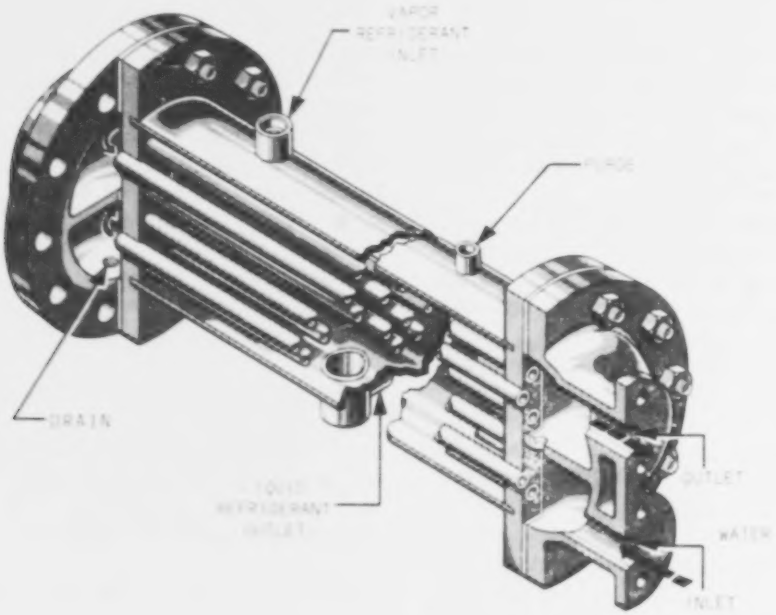
The capacity of the water-cooled condenser is affected by the temperature of the water, quantity of water circulated, and the temperature of the refrigerant gas. The capacity of the condenser varies whenever the temperature difference between the refrigerant gas and the water is changed. An increased temperature difference or greater flow of water increases the capacity of the condenser. The use of colder water can cause the temperature difference to increase.

Evaporative Condenser

An evaporative condenser operates on the principle that heat can be removed from condensing coils by spraying them with water or letting water drip onto them and then forcing air through the coils by a fan. This evaporation of the water cools the coils and condenses the refrigerant within them.

Liquid Receiver

A liquid receiver (fig. 10-13) serves to accumulate the reserve liquid refrigerant, to provide a storage for off-peak operation, and to permit pumping down the system. The receiver also serves as a seal against the entrance of gaseous refrigerant into the liquid line. When stop valves are provided at each side of the receiver for confinement of the liquid refrigerant, a pressure-relief valve is generally installed between the valves in the receiver and condenser equalizing line to protect the receiver against any excessive hydraulic pressure being built up. Receivers should never



47.95

Figure 10-20.—Water-cooled condenser.

be filled to exceed 80 to 90 percent of their total volume. If the pressure in the receiver should rise above the setting of the relief valve (usually about 225 psi), the relief valve will open and allow refrigerant to flow back into the condenser. Normally, on small units charged with R-12 or R-22, the relief valve vents to the atmosphere.

The receivers for units of very small capacity, equipped with air-cooled condensers, are frequently provided with FUSIBLE PLUGS or rupture disks in the end of the receiver shell. These fusible plugs replace the relief valves on larger units to protect the high-pressure side of the unit from abnormal or excessive pressures. The fusible plug consists of a hollow shell surrounding a core plug of low-melting point metal. Abnormally high pressures in the refrigerant system are accompanied by high-saturated refrigerant temperatures that melt the fusible core and relieve the pressure to the atmosphere.

EVAPORATORS

The evaporator is simply a bank or coil of tubing placed inside the refrigeration space. The tubing is filled with refrigerant at low pressure and low temperature. The refrigerant is a liquid as it enters the evaporator.

As the refrigerant circulates through the evaporator tubes, it absorbs its heat of vaporization from the surrounding space and substances. The absorption of this heat causes the refrigerant to boil. As the temperature of the surrounding space (and contents) is lowered, the liquid refrigerant gradually changes to a vapor. The refrigerant vapor then passes into the suction line by the action of the compressor.

Most evaporators used today are made of steel, copper, brass, stainless steel, aluminum, or almost any other kind of rolled metal that resists the corrosion of refrigerants and the chemical action of the foods.

There are two general types of evaporators: dry and flooded. The inside of a dry evaporator coil is always filled with a mixture of liquid and vapor refrigerant. At the inlet side of the coil, there is mostly liquid; but, as the refrigerant flows through the coil, it is vaporized until, at the end, there is nothing but vapor. In a flooded evaporator, a float level maintains liquid refrigerant at a constant level. As fast as the liquid refrigerant evaporates, more liquid is admitted by the float and, as a result, the entire inside of the evaporator is flooded with liquid refrigerant up to a certain level, determined by the float.

Evaporators are classified according to the method of evaporation: the direct-expanding type and the indirect-expanding type.

In the direct-expanding evaporator, heat is transferred directly from the refrigerating space through the tubes and absorbed by the refrigerant. In the indirect-expanding type, the refrigerant liquid or gas in the evaporator is used to cool some secondary medium, other than air. The secondary refrigerant maintains the desired temperature of the space and is usually brine—a solution of calcium chloride, or a mixture of chemicals of low-freezing point.

There are two methods of providing for the circulation of air within a refrigerated space. The cool air surrounding the evaporator must be moved to the stored food so heat may be extracted by conduction, and the warmer air from the food must be returned to the evaporator to be cooled. Natural convection can be used by installing the evaporator in the uppermost portion of the space to be refrigerated so the heavier cooled air will fall to the lower food storage section and the lighter food-warmed air will rise to the evaporator. In large refrigerated spaces, fans may be needed to provide the additional movement of the air to ensure that all areas are cooled.

CONTROL DEVICES

The effectiveness of modern refrigeration, for all systems, depends on automatic control. Automatic controls used with refrigeration systems usually provide for the control of the flow of liquid refrigerant, the on-off operation of the condenser cooling medium (such as water), and safety devices to prevent damage to the equipment. With a wide variety of control devices available, you will read about just the major classes of controls. Get to know the types of controls in the systems under your care. Learn what the manufacturer's instruction have to say.

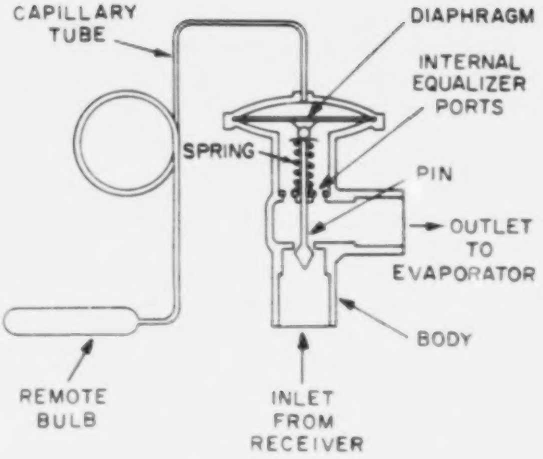
Control of Flow of Liquid Refrigerant

An expansion valve controls the flow of liquid refrigerant between the high side and the low side of the system. It is at the end of the line between the condenser and the evaporator.

Constant-Pressure Expansion Valve

A constant-pressure expansion valve, also called an automatic expansion valve, maintains a constant pressure in the evaporator.

Normally, the constant-pressure expansion valve is used only with direct-expansion dry-type of evaporators. In operation, the valve feeds enough liquid refrigerant to the evaporator to maintain a constant pressure in the coils. Because the temperature of the coils depends on the pressure, the temperature of the evaporator is governed by the expansion valve. This type of valve is generally used in a system where constant loads are expected. When a large variable load occurs and an automatic expansion valve is used, the valve will not feed enough refrigerant to the evaporator under high load and will overfeed the evaporator at low load. Compressor damage can result when slugs of liquid enter the compressor. Consequently, maintenance personnel should be alert to the difficulties that may arise from an automatic expansion valve.



54.286

Figure 10-21.—Thermostatic expansion valve.

Thermostatic Expansion Valve

Before discussing a thermostatic expansion valve, let us explain the term *superheat*. A vapor gas is superheated when its temperature is higher than the boiling point corresponding to its pressure. When the boiling begins, both the liquid and the vapor are at the same temperature. But in an evaporator, as the gas vapor moves along the coils toward the suction line, additional heat may be absorbed by the gas, and its temperature rises. The difference in degrees between the saturation temperature and the increased temperature of the gas is called "superheat."

A thermostatic expansion valve (fig. 10-21) tends to keep a constant superheat in the refrigerant vapor leaving the coil. This type of valve controls the flow of liquid refrigerant so that the evaporator coils have the correct amount of refrigerant at all times. A thermostatic expansion valve has a power element activated by a remote bulb. The bulb senses the degree of superheat in the suction line and causes the valve to open or close. Thermostatic expansion valves may have different remote bulb charges, two of which are the liquid charge and the gas charge. The conventional liquid charge uses the same refrigerant in the remote bulb as that used in the system proper. The remote bulb gas charge uses a limited amount of the same refrigerant used in the system. Manufacturers stamp or color code the valves to tell exactly what type of charge must be used in the bulb. Notice the internal equalizer ports that cause the vapor pressure on the bottom of the diaphragm to be the same as that released into the evaporator.

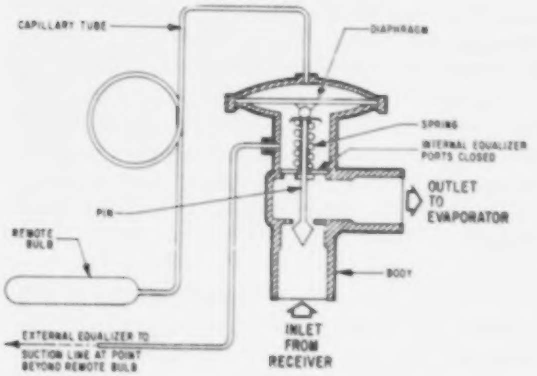
As the superheat in the suction line increases, the temperature, and therefore the pressure, of the refrigerant in the remote bulb increases. This increased pressure, applied to the top of the diaphragm, forces it down along with the pin that opens the valve. Liquid refrigerant from the receiver is admitted to the evaporator to replace that extracted by the compressor suction. This replacement has three effects. First, it provides additional liquid refrigerant to absorb heat from the evaporator. Second, it applies higher pressure to the bottom of the diaphragm, forcing it upwards and tending to close the valve. And third, it reduces the degree of superheat in the suction line by flowing more refrigerant through it. When the valve closes too far and restricts the refrigerant flow too much, the superheat rises and the cycle starts over. However, when the heat load remains constant, the valve position changes little. It will remain partially open to provide just the right amount of flow.

The use of internal equalizer ports, by applying the evaporator inlet pressure to the diaphragm, requires more superheat to open the expansion valve than do other means of equalization. The use of external equalization reduces the degree of superheat required to increase the opening of the valve by completing a line from the bottom of the diaphragm to the suction line, as shown figure 10-22. The lowest pressure in the system (suction pressure) is applied to the bottom of the diaphragm and requires the least amount of pressure (and degree of superheat) on its top to open the valve. As you can see, the thermostatic expansion valve with external equalization is the most sensitive to load changes.

The expansion of the liquid passing through the valve causes a reduction in temperature. Thus, any water in the liquid refrigerant can freeze, and the valve will not function properly. To help prevent freezing, you can install a drier between the receiver and the evaporator. The drier is filled with a dehydration agent, such as silica gel or activated alumina, and absorbs moisture from the liquid refrigerant. When moisture in the expansion valve freezes, note the condition of the drier to see if it is absorbing moisture.

Install the thermostatic expansion valve carefully to make sure it works right. Place the valve so you can get to it for inspection and service. Install it upright with the power assembly on top. Install a gas-charged valve so the valve body temperature is warmer than the thermal element temperature. Liquid-charged valves do not need this precaution.

Before applying heat to make up the soldered connections, remove the power assembly, cage assembly, and all gaskets. Keep heat away from all parts except the main body inlet and outlet connections. After reassembling the valve, clamp the thermal element or bulb tightly to the suction line from the cooling coil to make good metal-to-metal contact. The thermal element should be close to the outlet of the cooling coil on a horizontal portion of the suction pipe. Avoid locating it in any trapped portion. Where the suction pipe is under seven eighths of an inch outside diameter (O.D.), install the thermal element on top of the suction line. Where the suction line is seven eighths of an inch O.D. or larger, put the thermal element on the side of the pipe at a position of four o'clock, as shown in figure 10-23. The bulb and pipe should be insulated together with the insulation extended over each side of the bulb. Improper contact and insulation or location of the thermal element may cause liquid refrigerant to flood past the coil and may damage the compressor.


CAPILLARY TUBE
DIAPHRAGM
SPRING
INTERNAL EQUALIZER PORTS CLOSED
OUTLET TO EVAPORATOR
PIN
REMOTE BULB
BODY
EXTERNAL EQUALIZER TO SUCTION LINE AT POINT BEYOND REMOTE BULB
INLET FROM RECEIVER

54.286(54F)

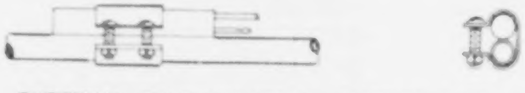
Figure 10-22.—Thermostatic expansion valve having external equalizer.

Low-Side Float Valve

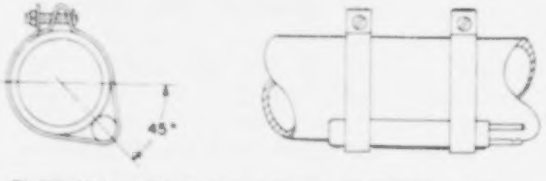
The low-side float valve controls the flow of liquid refrigerant where a flooded evaporator is used. It consists of a ball float in either a chamber or the evaporator itself on the low-pressure side of the system. The float actuates a needle valve through a simple lever mechanism. (See fig. 10-24.) As the float lowers, refrigerant enters through the open valve; as the float rises, the valve closes. One maintenance problem with this type of control is leaks in the ball float. A leaking float must be repaired or replaced, or a complete new valve assembly must be installed.

High-Side Float Valve

A high-side float expansion valve differs from the low-side control in that the valve float is in a liquid receiver or in an auxiliary container on the high-pressure side of the system. (See fig. 10-25.) From the condenser, the liquid refrigerant



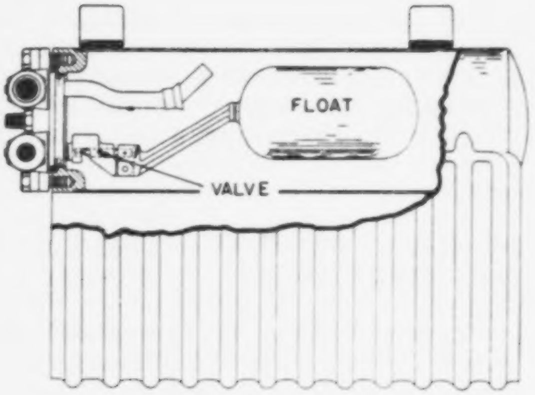
EXTERNAL BULB ON SMALL SUCTION LINE



EXTERNAL BULB ON LARGE SUCTION LINE

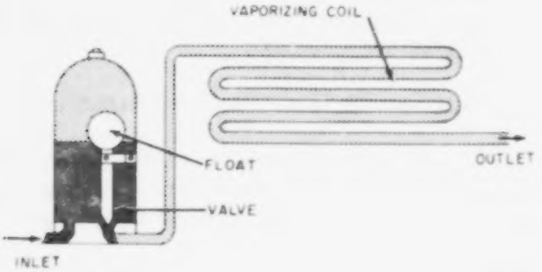
87.68

Figure 10-23.—Thermal element placement.



54.162

Figure 10-24.—A low-side float.



54.163

Figure 10-25.—A high-side float.

flows into the high-pressure float valve that immediately opens and allows the refrigerant to expand and pass into the evaporator. When the valve is equipped with a vent tube inside the valve, then the float valve may be installed at a higher elevation than the condenser without danger of the chamber becoming gas bound. As a pointer on maintenance, refrigerant charge is critical. Refrigeration is unsatisfactory with either an overcharge or an undercharge. Too much refrigerant floods back and damages the compressor. Too little refrigerant results in a capacity drop.

Capillary Tube

The capillary tube is another form of metering device. It consists of a long tube of small diameter. The length and diameter of the tube are important; any restrictions cause trouble in the system. The capillary tube is relatively simple in operation—no moving parts or adjustments. However, the capillary tube is best suited for household boxes, such as freezers and window air-conditioners, where the refrigeration load is reasonably constant and small horsepower motors are used.

The capillary tube, as does the high-side float valve, feeds liquid refrigerant to the evaporator as fast as it is produced by the condenser. While the condensing unit is running (air cooled by a fan or water cooled by the circulation of water), the operating characteristics of the capillary-tube equipped evaporator are the same as if it were equipped with a high-side float. The compressor may be controlled with either pressure or temperature control. Evaporators equipped with a capillary tube may not be paralleled on one condensing unit. The charge of refrigerant is balanced in the same ways with a high-side float.

Unlike the high-side float valve, the capillary tube does not close when the compressor stops. When the quantity of refrigerant in the system is correct, that is, when the charge is balanced, the flow of liquid refrigerant in the system is correct; or, when the charge is balanced, the flow of liquid refrigerant from the condenser to the evaporator ceases promptly after the compressor unit stops. A high-side float closes as soon as liquid is no longer available and the high-pressure side is separated from the low-pressure side of the system during idle cycle. When the compressor unit stops on a capillary tube system, liquid continues to flow as long as it lasts, after which hot high-pressure gas from the condenser flows into the evaporator until pressures are equalized. Because the evaporator is cold, hot gas condenses in the evaporator, and evaporator pressure rises slightly because of the heat of the hot gas. Equalization of pressure between the evaporator and the condenser makes starting of the compressor easy because there is not a great pressure difference across the compressor at the time of starting. Low-starting-torque motors may be used with capillary tube systems just as if the compressor were equipped with an unloading device between the discharge and suction sides of the compressor.

Prevent restrictions in the tubes, and use the proper refrigerant charge. Normally, capillary tubes are installed at the factory on package units. They are most often found on hermetically sealed units.

ACCESSORY DEVICES

The four basic or major parts of a refrigeration system just described are enough for a refrigeration unit to function. However, additional devices, such as the receiver already described, make for a smoother and more controlled cycle.

First, a source of power (which is usually electrical) is needed to drive the motor, which, in turn, operates the compressor that moves the refrigerant through its cycle. In chapter 6, motors were introduced and discussed briefly. Some of the other devices used on a refrigeration unit are briefly described in the following paragraphs in this section. Before proceeding, however, take a close look at figure 10-26 that shows one type of refrigeration system with additional devices installed. Starting at the compressor (high-side pressure), some of the devices and their functions are explained to help you understand installation and troubleshooting of a refrigeration unit.

RELIEF VALVE

A spring-loaded relief valve is installed in the compressor discharge line between the compressor discharge connection and the discharge line stop valve to protect the high-pressure side of the system from excessive pressures. This valve is located internally in some compressors. The discharge from the relief valve is led to the compressor suction line and, when the compressor discharge pressure becomes abnormally high from any cause, the relief valve opens and bypasses the discharge gas to the suction side of the compressor.

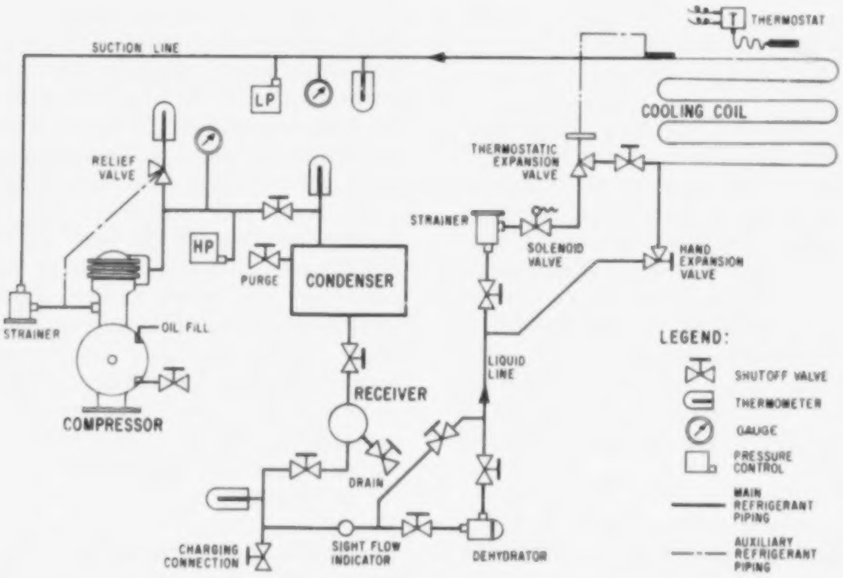
DISCHARGE PRESSURE GAUGE AND THERMOMETER

A pressure gauge and thermometer are installed in the compressor discharge line to show the pressure and temperature of the compressed refrigerant gas. The temperature shown is always higher than that corresponding to the pressure when the compressor is in operation, because of the initial condition of the compressor suction vapor and the work of the compression applied to the refrigerant during compression.

The compressor discharge line terminates at the refrigerant condenser.

COMPRESSOR-MOTOR CONTROLS

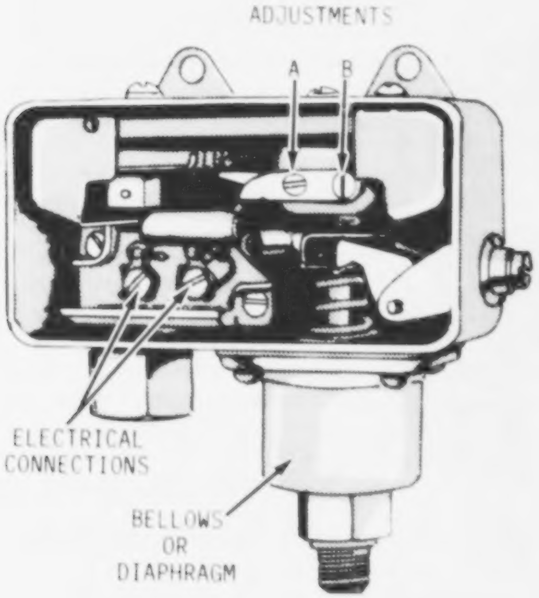
The starting and stopping of the compressor motor are usually controlled by either a pressure-actuated or temperature-actuated motor control.


SUCTION LINE
THERMOSTAT
T
LP
COOLING COIL
THERMOSTATIC EXPANSION VALVE
RELIEF VALVE
STRAINER
SOLENOID VALVE
HP
PURGE
CONDENSER
HAND EXPANSION VALVE
STRAINER
OIL FILL
COMPRESSOR
RECEIVER
LIQUID LINE
LEGEND:
SHUTOFF VALVE
THERMOMETER
GAUGE
PRESSURE CONTROL
MAIN REFRIGERANT PIPING
AUXILIARY REFRIGERANT PIPING
DRAIN
CHARGING CONNECTION
SIGHT FLOW INDICATOR
DEHYDRATOR

54.166

Figure 10-26.—A basic refrigeration system.

Temperature and pressure are directly related to each other. When the temperature of a refrigerant is increased, the pressure will increase; similarly, when the pressure changes, the temperature must also change. The operation of the pressure motor control depends on this relationship between pressure and temperature. A pressure motor control is shown in figure 10-27. The device consists of a low-pressure bellows, or in some cases a low-pressure diaphragm, connected by a small diameter tube to the compressor crankcase or to the suction line. The pressure in the suction line or the compressor crankcase is transmitted through the tube and actuates the bellows or diaphragm. The bellows move according to the pressure, and its movement causes an electric switch to start or stop the compressor motor. Adjustments, under the manufacturer's instructions, can be made on the "cutout" and "cut-in" pressures. Usually, the cutout pressure is adjusted to correspond to a temperature a few degrees below the desired evaporator coil temperature, and the cut-in pressure is adjusted to correspond to the temperature of the coil. When the difference between the cutout pressure and the cut-in pressure is large, a greater variation in cabinet temperature occurs. But with this large difference, the cycling time is increased. With a small pressure differential, the load or cabinet temperature is more uniform and the cycling time shortened.



77.119

Figure 10-27.—Pressure-actuated control.

The temperature motor control is much like the pressure device. The main difference is that a temperature-sensing bulb and a capillary tube replace the pressure tube. With the temperature motor control, the motor responds directly to the temperature in the cooled space. The cutout and cut-in temperature can be adjusted, and the difference between the two can be changed.

In addition, the refrigeration system may have a high-pressure safety cutout switch that shuts off the power to the compressor motor when the high-side pressure exceeds a preset limit. The construction of the high-pressure cutout is similar to that of the pressure motor control. The pressure tube is usually connected to the cylinder block and is actuated by excessive head pressure. When pressure exceeds the control limit because of too little condenser water, excessive noncondensible gases in the system, or for any other cause, the system stops and damage is prevented.

Maintenance personnel seldom have to repair compressor-motor controls. Normally, such repairs are made by the manufacturer. However, it is the responsibility of maintenance personnel to make correct adjustments on these controls to assure the smooth operation of the system. When the system must be shut down for repairs or maintenance work, the controls must be accurately set when the system is again placed in operation.

SOLENOID STOP VALVES

Solenoid stop valves, or magnetic stop valves, control gas or liquid flow. Found in many locations throughout the system, they are most commonly used to control the flow of liquid refrigerant to the expansion valve. The liquid refrigerant line is open for passage of refrigerant only when the compressor is in operation, and the solenoid is energized. The compressor motor and the solenoid stop valve are electrically in parallel; that is, the electrical power is applied to or removed from both simultaneously by the motor control switch. Thus, leakage of liquid refrigerant into the evaporator is prevented when the compressor is not running. A typical solenoid stop valve is shown in figure 10-28.

Solenoid stop valves may not operate properly because of a burned-out solenoid coil. The coil is normally replaced by a new one. However, foreign material may become lodged between the stem and the seat, and the valve will then leak fluid. This condition may be mistaken for an electrically defective valve. Before a valve is replaced or discarded, it should be carefully checked to see if it is still useful. The solenoid valve must be installed so that the coil and plunger are in a true vertical position. When the valve is cocked, the plunger will not reseat properly, causing refrigerant leakage.

THERMOSTAT SWITCH

Occasionally, a solenoid stop valve is operated directly by a thermostat located in the refrigerated space, and the compressor motor is controlled independently by a low-pressure switch. In this case, the thermostat can close the solenoid valve which stops the flow in the liquid line.

The solenoid valve control switch, or thermostat, makes and breaks the electrical circuit through the coil, thereby controlling the flow of liquid refrigerant to the expansion valve. The control bulb is charged with a refrigerant so that temperature changes of the bulb produce like changes in the pressure of the actuating vapor within the control bulb. These pressure changes are transmitted through the control tubing to the switch power element to operate the switch. The switch is adjusted to open the contacts and thus release the solenoid valve, stopping the flow of refrigerant to the cooling coil when the temperature of the refrigerated space has reached the desired point. The compressor, however, continues to operate until it has evacuated the evaporator. The resulting low pressure in the evaporator then activates the low-pressure switch which stops the compressor. As the temperature rises, the increase in bulb pressure closes the switch contacts, and the refrigerant is supplied to the expansion valve.

A pressure-operated motor control may be used as a thermostat by the addition of a small diameter tube and a bulb when the tube and bulb are properly charged.

REFRIGERANT LIQUID LINE

The refrigerant liquid accumulated in the bottom of the receiver shell is conveyed to the cooling coils through the main refrigerant liquid

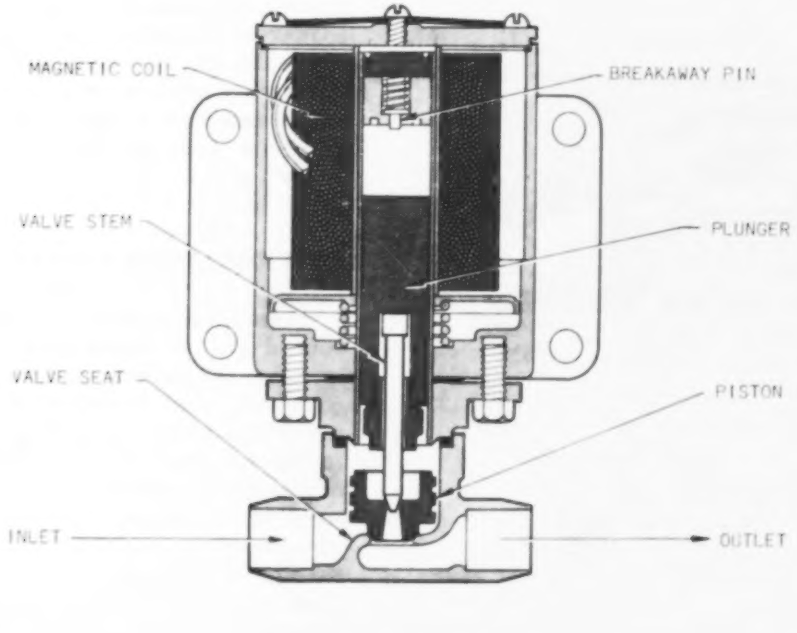


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Figure 10-28.—Solenoid valve.

line. A stop valve and thermometer are usually installed in this line next to each receiver. Where the sight-flow indicator and dehydrator assembly are close to the receiver, the built-in shutoff valves may be used instead of a separate shutoff valve.

DEHYDRATOR

A dehydrator (fig. 10-26), or drier, may be installed in the liquid line of a refrigeration system to remove moisture that would harm the system components and to reduce efficiency. When installed permanently in the line, it offers some resistance to flow and, for this reason, some manufacturers install it in a bypass line.

A dehydrator consists of a tubular shell with suitable fittings on each end, so it may be connected to the liquid line. A strainer in each end prevents any drying material from escaping from the dehydrator into the system. Dehydrators containing zinc chips for neutralizing the acidity of sulfur-dioxide refrigerating systems must not be used in R-12 or methyl-chloride systems.

Three approved desiccants (drying materials) are used in dehydrators. In order of preference they are silica gel, activated alumina, and drierite (calcium sulfate). Silica gel and activated alumina absorb moisture from the passing refrigerant, picking up water like a sponge. Silica gel and activated alumina are composed of millions of small pores. Drierite absorbs moisture by chemical action when moisture contacts it.

SIGHT-FLOW INDICATOR

A sight-flow indicator is installed in the liquid line. The sight-flow indicator is a special fitting provided with a gasketed glass port on each side and furnished with seal caps for protection when not in use. While a single-port indicator may be used, the double-port unit permits the use of a flashlight background, where space is available, for a clearer view. The refrigerant may be viewed passing through the pipe to determine the presence and amount of vapor bubbles in the liquid that would indicate low refrigerant or unfavorable operating conditions.

SUCTION LINE CONTROLS

Suction pressure regulators are sometimes placed between the outlet of the evaporator and the compressor to prevent the evaporator pressure from being drawn down below a predetermined level despite load fluctuations. These regulators are usually installed in systems that require a higher evaporator temperature than usual, such as in a milk cooler. When the evaporator pressure is allowed to drop too low, the corresponding temperature is below that desired and the milk freezes or the coils frost. Above the minimum pressure setting, the regulator is wide open and has no effect; but, as the pressure moves downward toward the setting, the regulator begins to close and automatically maintains the desired minimum pressure.

Suction pressure control switches, often called low-pressure cutouts, are sometimes connected to a tee in the suction line. They are essentially a single-pole, single-throw electrical switch and are mainly used to control starting and stopping of the compressor. The refrigerant suction pressure acts on the metallic bellows of the power element of the switch and produces movement of a lever mechanism operating electrical contacts. A rise in pressure closes the switch contacts and thereby completes the pilot circuit of the motor controller which, in turn, starts the compressor automatically. As operation of the compressor gradually decreases the suction pressure, the movement of the switch linkage reverses until the contacts are separated at a predetermined low-suction pressure, thus breaking the motor controller pilot circuit and stopping the compressor.

SUCTION LINE STRAINER

A suction strainer is provided at the compressor suction line connection to protect the moving parts of the compressor from dirt, scale, and filings that may find their way into the refrigerant piping system when a system is opened because of initial installation, inspection, or maintenance. This strainer on late model compressors is inside the compressor and is removable through a flanged connection.

GAUGES AND THERMOMETERS

Between the suction line stop valve and the compressor, a pressure gauge and thermometer may be provided to show the suction conditions at which the compressor is operating. The thermometer shows a higher temperature than the temperature corresponding to the suction pressure, as indicated by the gauge, because the refrigerant vapor becomes superheated during its passage from the evaporator to the compressor through the suction liquid heat exchanger (where used) and by heat leakage to the suction line insulation. All refrigerating plant gauge lines are provided with cutout valves near the gauge for use in derangement. Standard thermometers are used and the thermometer wells may be of the screwed type. The threaded joint is seal welded or silver brazed to a piping system fitting to prevent leakage.

ACCUMULATORS AND OIL SEPARATORS

Liquid refrigerant must never be allowed to enter the compressor. Liquids are noncompressible; that is, when pressure is applied, their volume remains the same. If liquid refrigerant were allowed to enter the compressor, it would be trapped between the piston and the cylinder head. When the piston attempted to compress it, the total pressure would be applied to the liquid, the piston, the rings, and the cylinder head. One of these mechanical parts would probably break.

In refrigeration systems with high-side floats, liquid refrigerant may leave the evaporator at the end of the "on" cycle. To prevent the liquid refrigerant from reaching the compressor, you collect it in a small tank, called an accumulator (fig. 10-29). This trapped liquid refrigerant boils off at the beginning of the next "on" cycle.

In the design and installation of refrigeration systems, oil from the compressor must not move into the rest of the refrigeration system. Oil in the lines and evaporator reduces the efficiency of the system. Because the compressor contains both the refrigerant gas and lubricating oil, they will mix. Oil separators between the compressor and the condenser remove this oil; the refrigerant is a gas and is least able to retain the oil. Oil separators (fig. 10-30) contain screens, baffles, and draining facilities to increase the efficiency of separation.

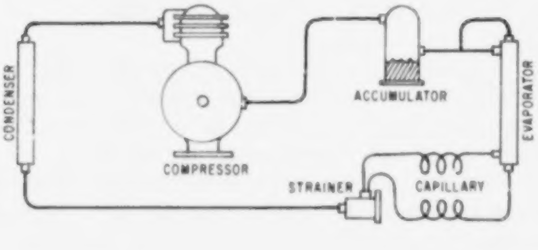

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Figure 10-29.—Accumulator location.

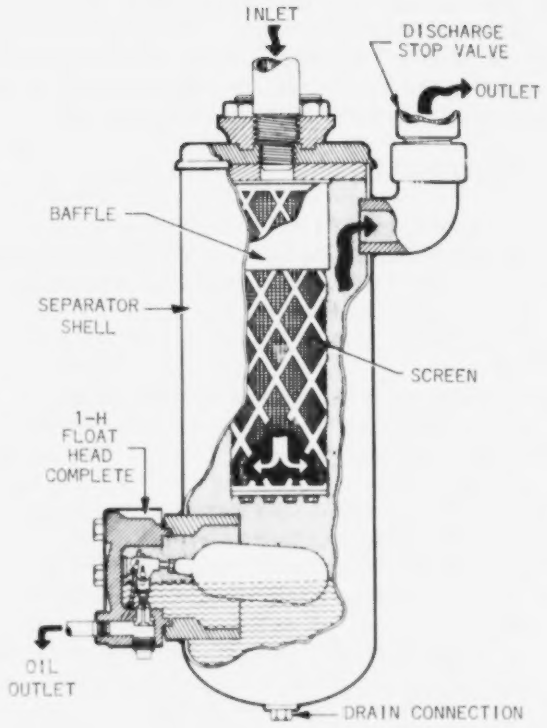

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Figure 10-30.—Cutaway view of an oil separator.

Figure 10-31 shows a separator installed in a refrigeration system.

REFRIGERANTS

The refrigerants in common use are fluids and are affected by heat, temperature, and pressure. Many different fluids are used as refrigerants, their selection is based on low-boiling points and other desirable characteristics. Three common refrigerants used in refrigeration systems are dichlorodifluoromethane (or R-12), monochlorodifluoromethane (or R-22), and refrigerant 502 (or R-502).

These are PRIMARY REFRIGERANTS, because each one changes its state upon the application or absorption of heat, and in this act of change absorbs and extracts heat from an area or substance. The *primary refrigerant* is so termed because it acts directly upon the area or substance, although it may be enclosed within a system.

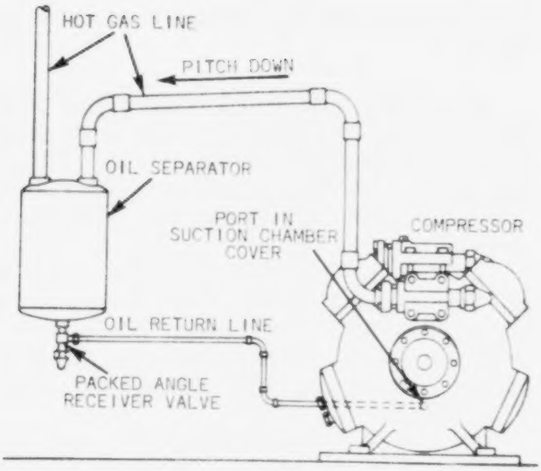

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Figure 10-31.—Installation of an oil separator.

For a primary refrigerant to cool, it must be placed in a closed system in which it can be controlled by the pressure imposed upon it. The refrigerant can then absorb at the temperature ranges desired. If a primary refrigerant were used without being controlled, it would absorb heat from most perishables and freeze them solid.

SECONDARY REFRIGERANTS are substances, such as air, water, or brine. Though not refrigerants in themselves, they have been cooled by the primary refrigeration system; they pass over and around areas and substances to be cooled; and they are returned with their heat load to the primary refrigeration system. Secondary refrigerants pay off where the cooling effect must be moved over a long distance and gastight lines cost too much.

DICHLORODIFLUOROMETHANE (R-12)

Pure dichlorodifluoromethane (CCl_2F_2), commonly referred to as R-12, is colorless and odorless in concentrations of less than 20 percent by volume in air; in higher concentrations, its odor resembles that of carbon tetrachloride. It has a boiling point of −21.6°F at atmospheric pressure, and at ordinary room temperatures is a liquid when under pressure of about 70 to 75 psig. R-12 vapor and air mixtures, in all proportions, are nonirritating to the eyes, nose, throat, and lungs. The refrigerant will not contaminate or poison foods or other supplies that it may contact. The vapor is nonpoisonous but will not support respiration and produces mild anesthesia when enough is inhaled. In view of the low-boiling point at atmospheric pressure, prevent liquid R-12 from contacting the eyes because of the possibility of freezing. The liquid is nonflammable and nonexplosive, and its air mixtures cannot spread a flame. It does not corrode metals commonly used in refrigerating apparatus.

One hazard of R-12 as a refrigerant is the health risk should leakage of the vapor come into direct contact with an open flame of high temperature (about 1022°F) and be decomposed into phosgene gas, which is highly toxic.

While working with halocarbons (refrigerants), follow the safety guidelines below.

1. Consult local health and safety authorities for specific hazard control information based upon the particular kind of exposure. Additional guidance will be announced to ALCON in the near future.

2. In high concentrations, halocarbons are toxic chemicals. Any handling or usage requires the following minimum personal protective measures. (Clothing and equipment must be impervious or resistant to halocarbons.)

NOTE: Nonimpervious (nonresistant) clothing which becomes wet with halocarbons must be immediately removed and not reworn until all traces of the chemical are removed by cleaning.

a. Full-length face shield or chemical worker's goggles

b. Apron or coveralls (both may be required)

c. Elbow-length gloves

d. Boots or booties

e. Positive-pressure respiratory protection available for emergency exit when using bulk or large quantities of halocarbons

NOTE: Respiratory protection in use may also be required for certain operations, depending upon the magnitude and the duration of the potential exposure. (Consult health and safety authorities for detailed guidance.)

3. During all primary maintenance or industrial uses of halocarbons, such as flushing or recharging refrigeration or air-conditioning systems, the following "good engineering" precautions are mandatory:

a. Strict compliance with NSTM Gas Free Engineering procedures for entry into enclosed or confined spaces, and close adherence to standard operating procedures for all halocarbon maintenance actions.

b. Tested and operational ventilation systems, supplemented by portable equipment as necessary, to provide intake from and exhaust to the atmosphere (not recirculation) sufficient to maintain halocarbon concentration at acceptable limits (consult health and safety personnel) until the maintenance action has been completed. Local exhaust ventilation capable of maintaining a minimum capture velocity of 100 fpm over the face of the container or operation is normally required to maintain vapor limits within acceptable limits.

c. Positive pressure emergency breathing devices with supplied air available in the space for instant donning and exiting in a halocarbon mishap.

d. Established two-way communications between the halocarbon pump at the bulk source and the equipment being filled, cleaned, or flushed. A backup sound-powered system is recommended.

e. Verification of the filling and flushing system integrity by leak testing (e.g., a pressure drop test) before halocarbon operations commence.

f. Minimum of two people stationed in the space, with a safety observer (tender), near the exit route if available. Provide rescue equipment (as necessary) to quickly remove personnel from the space in an emergency. Rescue personnel should also be equipped with protective clothing and positive-pressure respiratory protection.

g. Medical department representative who is trained and knows the physiological effects, the prescribed first aid, and the emergency treatment for halocarbon mishaps should be alerted to the maintenance action under way and should be standing by for quick response.

h. An emergency eyewash/shower system close to all halocarbon operations should its use be required. Where a permanent system is not available, a portable system of 5- to 10-gallon capacity should do. Only potable water may be used for this purpose.

R-12 is a stable compound capable of undergoing the physical changes without decomposition to which it is commonly subjected in service. It is an excellent solvent as a liquid; it loosens and removes dirt, scale, or oil that it may contact within a refrigeration system.

MONOCHLORODIFLUOROMETHANE (R-22)

Monochlorodifluoromethane ($CHClF_2$), commonly called R-22, is a synthetic chemical specially developed for refrigeration installations that have a very low-temperature cooling unit, such as in a fast-freezing unit that maintains a temperature of −20°F to −40°F.

The boiling point of R-22 is −41.4°F at atmospheric pressure. This refrigerant is very stable and is nontoxic, noncorrosive, nonirritating, and nonflammable. R-22 when in contact with an open flame will decompose into phosgene gas.

Of the many refrigerants available, R-12 and R-22 are used the most for SEABEE type of applications. These two refrigerants cover the range in temperature from comfortable air conditioning to cold-storage plants. However, at some locations, you may find other primary refrigerants being used, such as ammonia, methyl chloride, or sulfur dioxide.

R-502 REFRIGERANT (R-22 + R-115) ($CHClF_2/CClF_2CF_3$)

Refrigerant R-502 is an azeotropic moisture of 48.8 percent R-22 and 51.2 percent R-115. It has been used since 1961. See table 10-3 for its pressure temperature relationships.

Azeotropic refrigerants are liquid mixtures of refrigerants that exhibit a constant maximum and minimum boiling point. However, these mixtures act as a single refrigerant.

It is a nonflammable, noncorrosive, practically nontoxic liquid. A good refrigerant for obtaining medium and low temperatures, it is suitable where temperature from 0°F to −60°F (−18°C to −51°C) are needed. It is often used in frozen food lockers, frozen food processing plants, frozen food display cases, and in storage units for frozen foods and ice cream. It is only used with reciprocating compressors.

The boiling point is −50.1°F (−46°C) at atmospheric pressure. When working on a unit that uses R-502, note that the cylinder head is normally identified with an orchid color.

ADDITIONAL PRIMARY REFRIGERANTS

In addition to R-12 and R-22, other chemicals may be used as refrigerants as long as their boiling point at atmospheric pressure

Table 10-3.—Pressure Temperature Relationship of R-502

	PRESSURE	
Temp. F.	Psia	Psig
−100	3.230	23.34*
− 75	7.318	15.02*
− 50	14.74	0.04
− 25	27.02	12.33
− 20	30.22	15.52
− 15	33.69	18.99
− 10	37.46	22.76
− 5	41.53	26.84
0	45.94	31.24
5	50.68	35.99
10	55.79	41.09
15	61.27	46.57
20	67.14	52.45
25	73.42	58.73
50	111.6	96.89
75	162.7	148.0
86	198.8	175.1
100	229.1	214.4
125	313.4	298.7
150	418.6	403.9
160	467.3	452.6

*Inches of mercury below one atmosphere.

is less than the desired temperature in the evaporator.

R-717, or ammonia (NH_3), often used as a primary refrigerant, has a boiling point of approximately −28 °F at atmospheric pressure and absorbs 565 Btu of latent heat per pound of refrigerant at 5 °F. However, anhydrous ammonia is extremely dangerous to personnel in that when splashed on the skin or into the eyes it burns by actively seeking water from the areas affected. The first-aid procedures include restoring this water by flooding the area. Always stand to one side when opening or closing an ammonia valve. R-717 is also very corrosive with copper or bronze in the presence of even a small amount of moisture.

Azeotropic refrigerants are combinations of individual refrigerants and possess different characteristics than either of their component refrigerants. As one example, R-500, composed of 73.8 percent R-12 and 16.1 percent R-152a, has a boiling point of −28 °F at atmospheric pressure and absorbs 82.45 Btu of latent heat per pound of refrigerant at 5 °F.

All refrigerants have their own characteristics. It is extremely important to charge a system with the refrigerant specified. Use of an incorrect refrigerant can lead to reduced efficiency, mechanical problems, and dangerous conditions.

SAFETY IN HANDLING REFRIGERANT

In operating refrigerating machines, see that only the gas for which the particular type of machine is designed to operate is introduced into the system. Introduction of improper gases will, in some cases, result in violent explosions and either completely demolish the machine or render it inoperative.

PERSONAL PROTECTION

Since R-12, R-22, and R-502 are nontoxic, you will not have to wear a gas mask when servicing equipment in which they are contained unless they can decompose. However, protect your eyes by wearing splashproof goggles to guard against liquid refrigerant freezing moisture in your eyes. Whenever you loosen a connection that relates to R-12, R-22, and R-502, protect your eyes.

When liquid R-12, R-22, and R-502 contact the eyes, get the injured person to the medical officer at once. Avoid rubbing or irritating the eyes and give the following first-aid treatment immediately.

FIRST. Drop sterile mineral oil into the eyes to irrigate them.

SECOND. Wash the eyes when irritation continues with one of the following:

1. A weak boric acid solution
2. A sterile salt solution not to exceed 2 percent salt

When liquid R-12, R-22, and R-502 contact the skin, flush the affected area repeatedly with water. Strip refrigerant-saturated clothing from the body, wash the skin with water, and take the patient immediately to the dispensary.

Should a person be overcome in a space which lacks oxygen because of a high concentration of refrigerant, treat the victim as a person who has experienced suffocation; i.e., through artificial respiration.

For more help in rendering first aid to victims of accidents with refrigerants, get a copy of the

Standard First Aid Training Course, NAVEDTRA 10081-C.

HANDLING REFRIGERANT CYLINDERS

Never drop the cylinders nor permit them to strike each other violently.

Never use a lifting magnet nor a sling (rope or chain) when handling the cylinders. A crane may be used when a safe cradle or platform is provided to hold the cylinders.

Caps for valve protection should be kept on the cylinders, except when the cylinders are in use.

Whenever refrigerant is discharged from a cylinder, immediately weigh the cylinder and record the weight of refrigerant remaining in the cylinder.

Never use the cylinders for rollers, supports, or for any purpose other than to carry gas.

Never tamper with the safety devices in the valves or the cylinders.

Open the cylinder valves slowly. Never use wrenches or tools, except those provided or approved by the gas manufacturer.

Make sure that the threads on regulators or other connections are the same as those on the cylinder valve outlets. Never force connections that do not fit.

Regulators and pressure gauges designed for a particular gas must not be used on the cylinders containing different gases.

Never attempt to repair or alter cylinders or valves.

STORAGE OF COMPRESSED GAS CYLINDERS

Cylinders may be stored in the open, but should be protected against extremes of weather. During the winter, the cylinders stored in the open should be protected against an accumulation of ice or snow. In the summer, the cylinders stored in the open should be screened against continuous direct rays of sunlight.

No part of any cylinder containing compressed gas should ever be exposed to a temperature above 120°F. A direct flame or jet of steam should never contact any part of a compressed gas cylinder.

Never store the cylinders near highly flammable substances, such as oil, gasoline, or waste.

Cylinders should not be exposed to continuous dampness, salt water, or salt spray.

Store full and empty cylinders apart to avoid confusion.

Do not store full cylinders near elevators or gangways or where heavy moving objects may strike or fall on them.

Protect the cylinders from any object that will cut or abrade the surface of the metal.

REFRIGERATION EQUIPMENT

Refrigeration equipment may be grouped as self-contained and remote.

With self-contained refrigeration equipment, the cabinet houses both the insulated refrigerating storage compartment in which the evaporator is located, and also the uninsulated compartment in which the condensing unit is located. Such refrigerating equipment may be designed either with a hermetically sealed, a semisealed, or an open condensing unit. In any case, it is completely assembled and charged at the factory and comes ready for use with little or no installation work. Self-contained refrigerating equipment may include domestic refrigerators, water coolers, reach-in and walk-in refrigerators, small cold-storage plants, ice plants, and so on.

Remote refrigerating equipment has the box or cabinet installed in one space, and the condensing unit is installed in a remote location. The reason for locating the condensing unit outside of the cabinet may be to devote all of the cabinet space to the freezer. Also, the condenser may be too large to install in the cabinet. Furthermore, one may not want the heat liberated from the condenser to enter the space around the refrigerator; for example, a refrigerator in an air-conditioned hospital.

REACH-IN REFRIGERATORS

Reach-in refrigerators are similar in design, purpose, and general usage to those used in civilian markets and restaurants. They have a storage capacity of 15 cubic feet or more. At Navy installations, they are used to store perishable foods in galleys and messes. They are also used in hospitals to store biologicals, serums, and other medical supplies requiring temperatures between 30°F and 45°F. Standard size units most frequently used are those with storage capacities of 15, 20, 30, 45, 65, and 85 cubic feet. The larger sizes are often equipped with a full height compartment and door, and with rails and hooks for hanging large cuts of meat. Observe figure 10-32 that shows a typical reach-in refrigerator with a detached condensing unit.

Exterior finishes for reach-in refrigerators are porcelain-on-steel, lacquered or enameled steel, aluminum, and stainless steel. Interior finishes are usually porcelain-on-steel or wood, such as seasoned gum, fir, or spruce. Shelves are made of plated metal strips, slatted wood, or wire. Insulation is sealed against moisture and is usually board or batten type. Wall thickness averages 4 inches, with 2 inches of insulation for wood exteriors and interiors. However, in cabinets in kitchens, 5-inch walls with 3 inches of insulation are common.

Reach-in refrigerators are usually self-contained units with an air-cooled condensing unit enclosed in an uninsulated compartment or cabinet. A typical unit is shown in figure 10-33. The wall or panel type of unit cooler is mounted on the rear wall of the food compartment. In operation, warm air is drawn by the fan into the upper part of the unit cooler where it passes over the evaporator coils, is cooled, and then is discharged at the bottom of the cooler. The air then passes up and through the interior and around the contents of the refrigerator. The cycle is completed when the air again enters the evaporator.

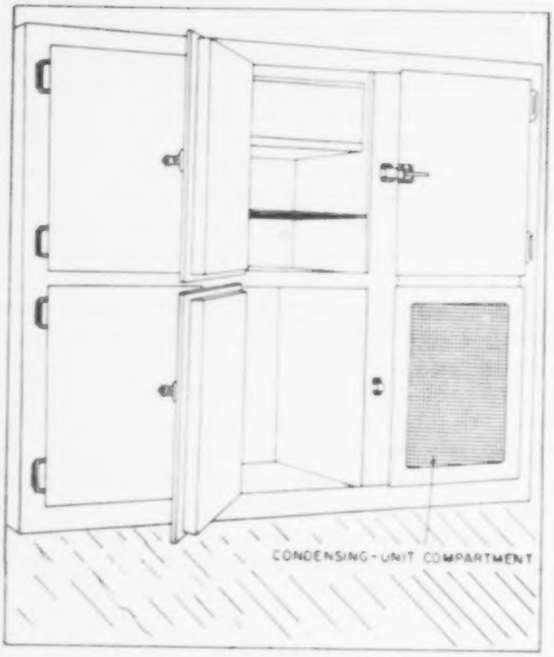

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Figure 10-33.—Self-contained reach-in refrigerator.

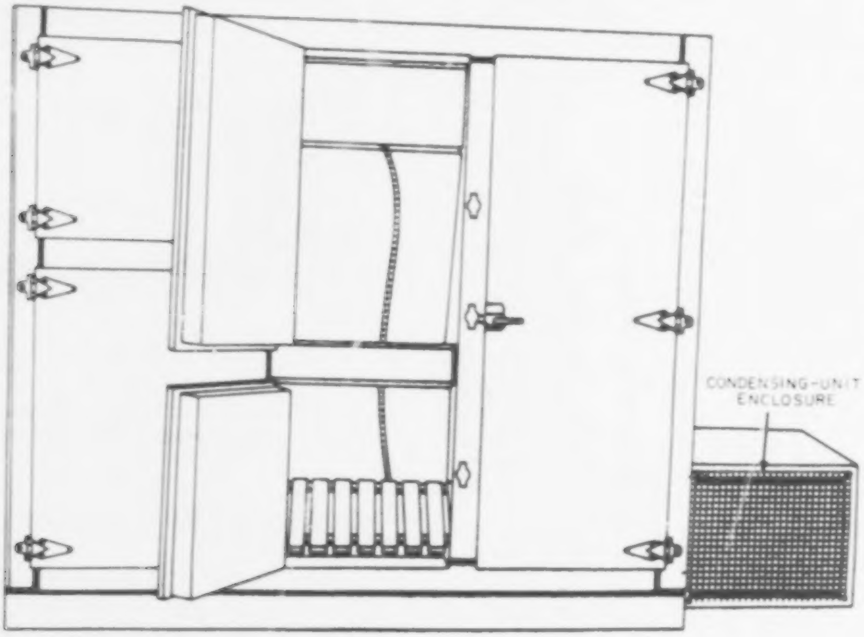

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Figure 10-32.—Exterior of reach-in refrigerator with remote condensing unit.

Although reach-in refrigerators are normally self-contained systems, in larger refrigerators remote condensing units are sometimes used. Remote type of reach-in refrigerators do not have the condensing unit installed in the refrigerator cabinet. The condensing unit may be near or far from the cabinet. Figure 10-34 shows a 65-foot and a 45-foot refrigerator next to each other. Note the air-cooled condensing units mounted one above the other. Usually, open type of compressors are used. However, in small capacity units, the trend has been toward hermetic type of compressors.

Evaporators in reach-in refrigerators are generally the unit cooler type with dry coils. (See fig. 10-35.) In smaller capacity refrigerators, ice-making coils similar to those used in domestic refrigerators are often used. Also, straight gravity coils are also found. The refrigerant is normally R-12.

The refrigerant is metered to the evaporator through a thermostatic expansion valve in both remote and self-contained types. The low-pressure control is set to operate the evaporator on a self-defrosting cycle, and temperature is thus controlled. Another type of control system uses both temperature and low-pressure control of defrost on each cycle. The evaporator fan is wired for continuous operation.

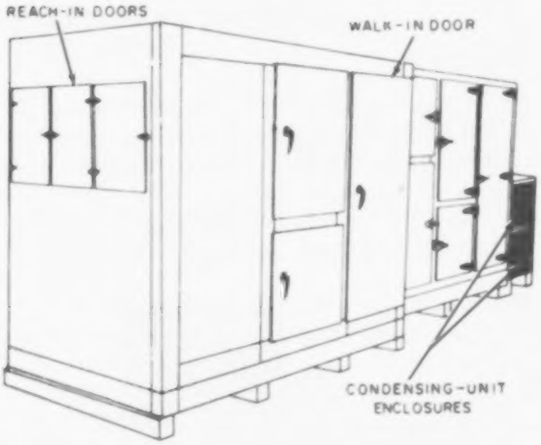

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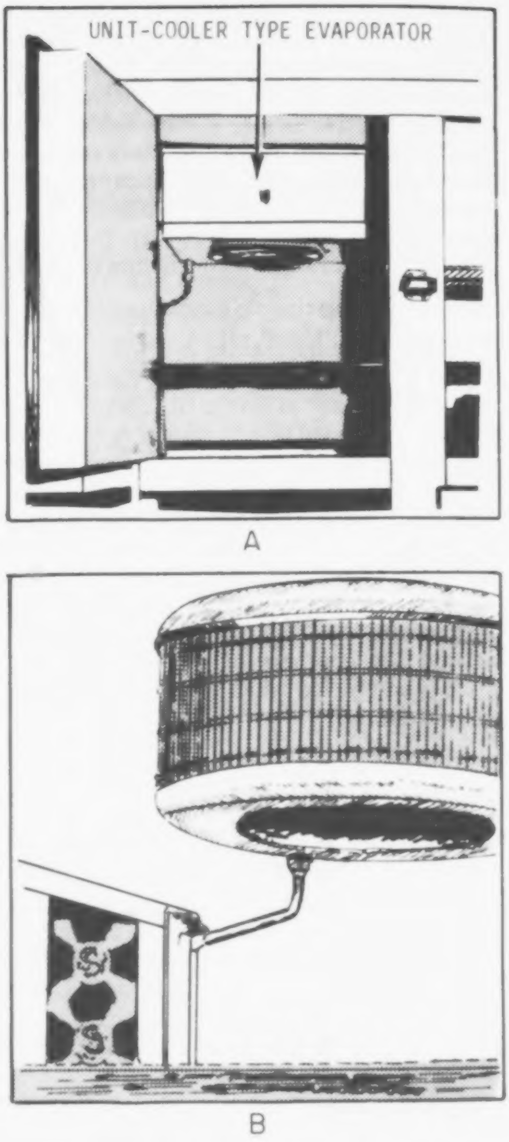
Figure 10-34.—Remote type of 65- and 45-cubic-foot reach-in refrigerators.

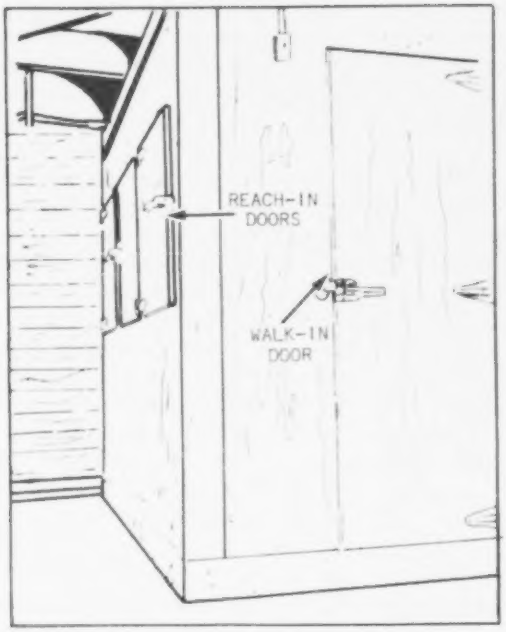


48.21(54)G

Figure 10-35.—A. Unit cooler in a reach-in refrigerator. B. Dome cooler in a reach-in refrigerator.

WALK-IN REFRIGERATORS

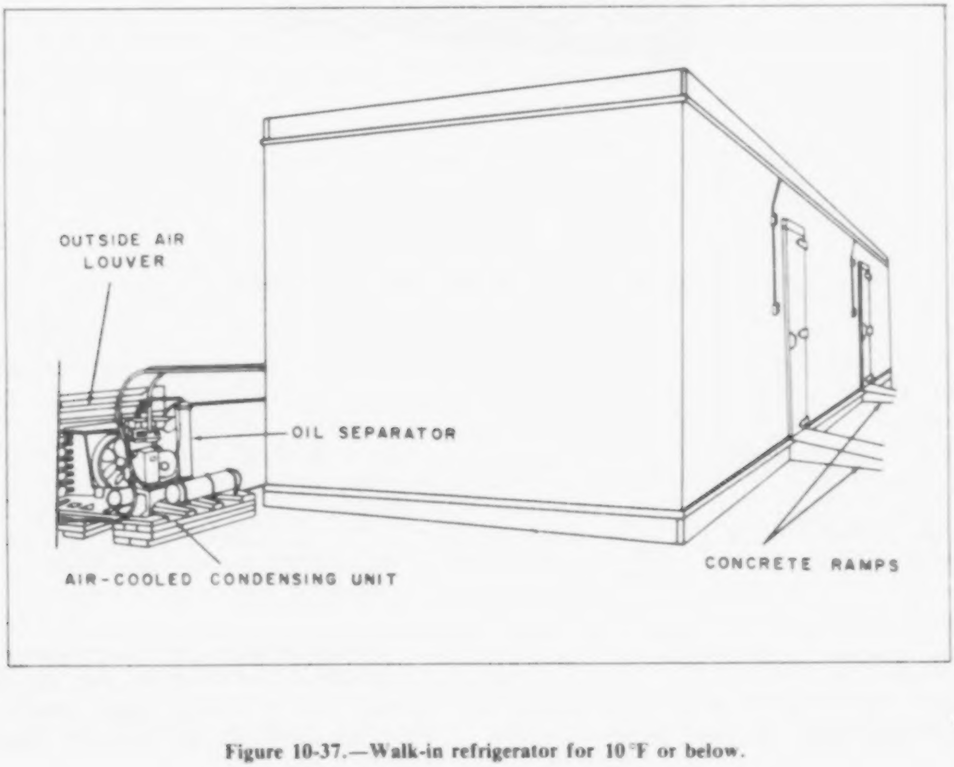
Walk-in refrigerators are normally larger than reach-in types and are described as built-in or prefabricated sectional walk-in units. They are made in two types: one for bulk storage of fresh meats, dairy products, vegetables, and fruits requiring temperature from 35 °F to 38 °F and the



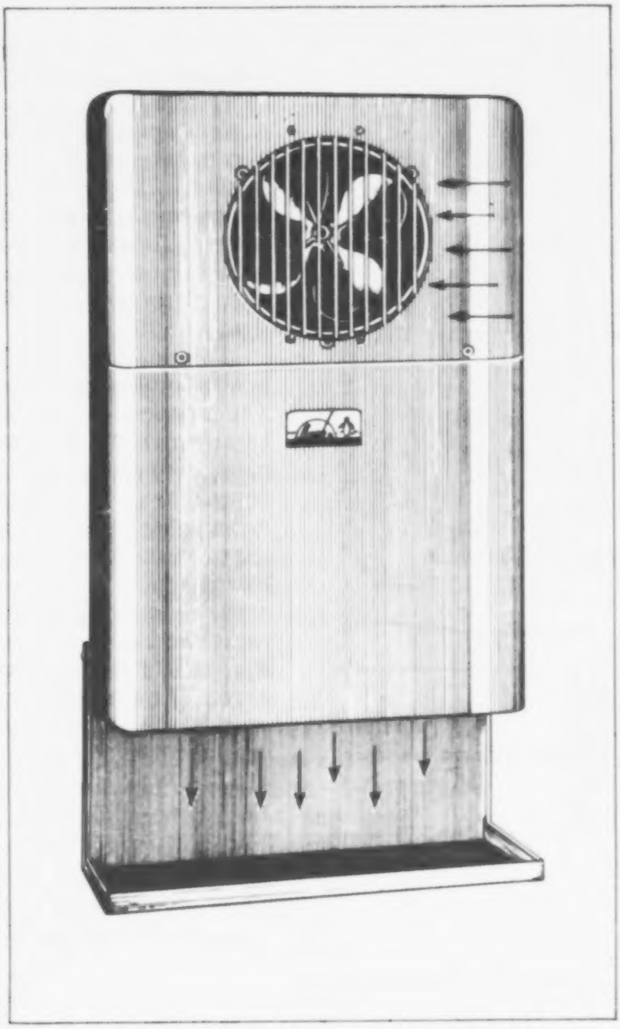
48.21(54)h
Figure 10-36.—Walk-in refrigerator with reach-in door.

other for the storage of frozen food at temperatures of 10°F, or below. These 35°F to 38°F refrigerators are built and shipped in sections and assembled at the installation. They may be taken apart, moved, and reassembled as required. Larger sizes may have two or three compartments to allow for separation of different types of foods. Standard size coolers are 4 feet by 6 feet or larger in floor area. A walk-in refrigerator with reach-in doors is shown in figure 10-36.

The exteriors of walk-in refrigerators are of painted or varnished wood or are metal covered. The interiors are of filled and shellacked or varnished wood. Insulation is made of board or batten and sealed against moisture. For storage temperatures between 35°F and 40°F, 3 or 4 inches of insulation is generally used. For low-temperature application, such as the storage of frozen foods, 5 or more inches of insulation is used. These refrigerators are equipped with meat racks and hooks to store meat carcasses. Small size walk-in refrigerators have shelves as well as racks. The compressor and condenser units are outside the main structure. The walk-in type designed for 10°F or below (fig. 10-37) is similar



48.21(54)J
Figure 10-37.—Walk-in refrigerator for 10°F or below.



54.289

Figure 10-38.—Wall-mounted panel type of evaporator.

to the 35°F to 38°F-type, except the insulation is usually about 1 1/2 times thicker, and meat hooks or rails are not provided, because frozen food is usually stacked on dunnage.

The operation of walk-in refrigerators is similar to that of reach-in units. The evaporator must have sufficient capacity (Btu per hour) to handle the heat load from infiltration and product load. The condenser is sized to handle the evaporated Btu per hour plus the heat added by the compressor. In the field, the condensing units are rated by their capacity to remove heat during a 1-hour period. Evaporators are made in several forms; their selection depends on the conditions under which they are to operate. Both gravity-type and forced-air evaporators are used, and normally there is little difference in the results. The operation of the forced-air evaporator is normally a continuous cycle. Warm air in the refrigerator box is drawn into the fan and forced over the evaporator coils where it is cooled and is blown back into the box when the fan is operating. Occasionally, maintenance personnel may hear that stored products in a refrigerator are being dehydrated or dried out. Forced-air evaporators can cause dehydration because the product is stored in a high-velocity zone. Gravity coils, on the other hand, do not have this disadvantage.

The condensing unit is generally outside of the main structure. Either air-cooled or water-cooled condensers may be used. The warm air coming off the condenser is blown outside of the building through air louvers.

Evaporators used in walk-in refrigerators may be the wall type with forced-air blowers, or they may be the plate type. Circulation of cooling air is required in refrigerators of this type to maintain a fairly constant temperature throughout the storage area. The warm air from the cold-storage compartment is drawn in by the fan at the top of the evaporator. The air is cooled as it passes around the evaporator coils. The cool air is then discharged at the bottom of the evaporator. Figure 10-38 shows a wall-mounted evaporator. The plate type of evaporators are shown in figure 10-39. These types are hung in banks, after being fabricated and assembled complete with a thermostatic expansion valve and a heat exchanger. Circulation of the air around the evaporators is by natural convection drafts.

A thermostatic control is inside the cold-storage room for temperature control. A solenoid valve in the liquid line of the compressor is opened and closed by the thermostatic control. A suction-pressure switch controls operation of the compressor. A high-pressure cutout switch is sometimes provided.

LOGS

In operating or standing watch on refrigerating or air-conditioning equipment, the Utilitiesman may be responsible for keeping a daily operating log on the equipment. Try to keep the logs neat and clean. Make sure, also, that information recorded on them is accurate and legible.

Operating logs may help to spot trouble in the equipment. They are also useful in programming and scheduling maintenance work. Also, operating logs may provide a means of self-protection when trouble occurs and the cause can be placed on the individual.

Good judgment must always be used in the analysis of service troubles and specific corrections should be followed wherever possible. One of the best methods for determining when and what corrective measures are necessary for a plant which is not operating properly is to compare the pressures and temperatures at various parts of the system with corresponding readings taken in the past when the plant was operating properly under similar heat load and circulating water temperature conditions.

A typical daily operating log (NAVSEC 9590/1) for refrigerating equipment is shown in

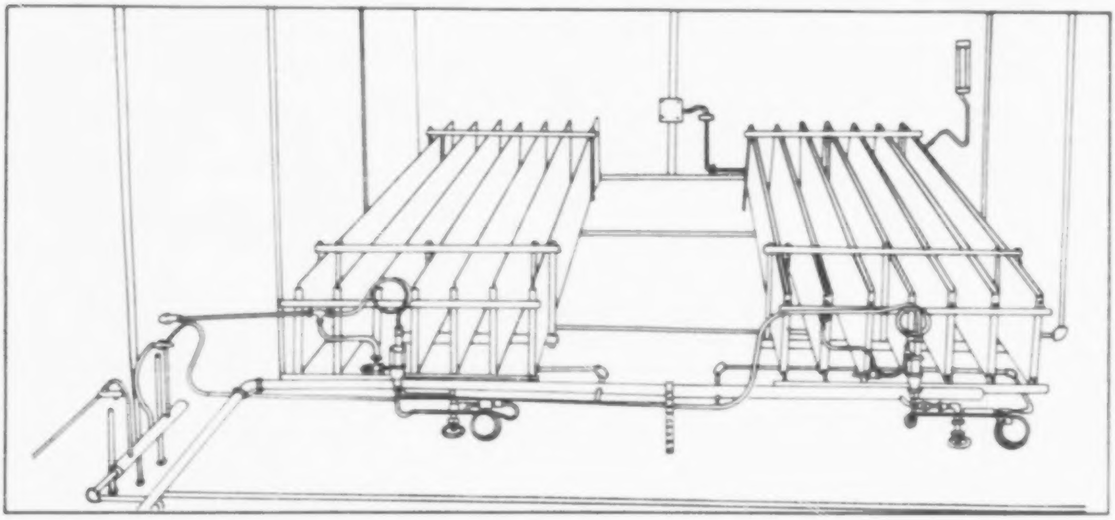


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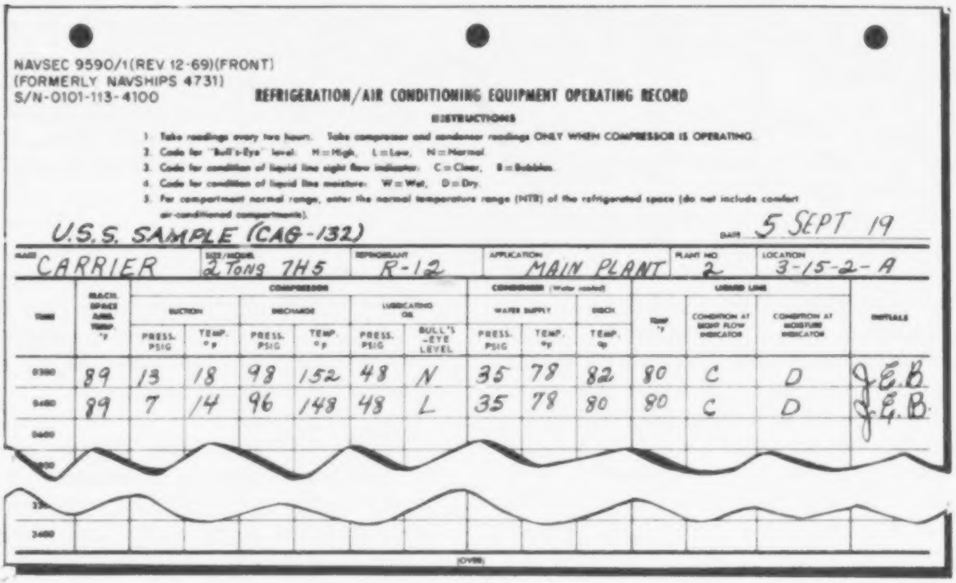
Figure 10-39.—Plate type of evaporators.



NAVSEC 9590/1(REV 12-69)(FRONT)
(FORMERLY NAVSHIPS 4731)
S/N-0101-113-4100

REFRIGERATION/AIR CONDITIONING EQUIPMENT OPERATING RECORD

INSTRUCTIONS

1. Take readings every two hours. Take compressor and condenser readings ONLY WHEN COMPRESSOR IS OPERATING.
2. Code for "Bull's-Eye" level: H = High, L = Low, N = Normal.
3. Code for condition of liquid line sight flow indicator: C = Clear, B = Bubbles.
4. Code for condition of liquid line moisture: W = Wet, D = Dry.
5. For compartment normal range, enter the normal temperature range (NTR) of the refrigerated space (do not include comfort air-conditioned compartments).

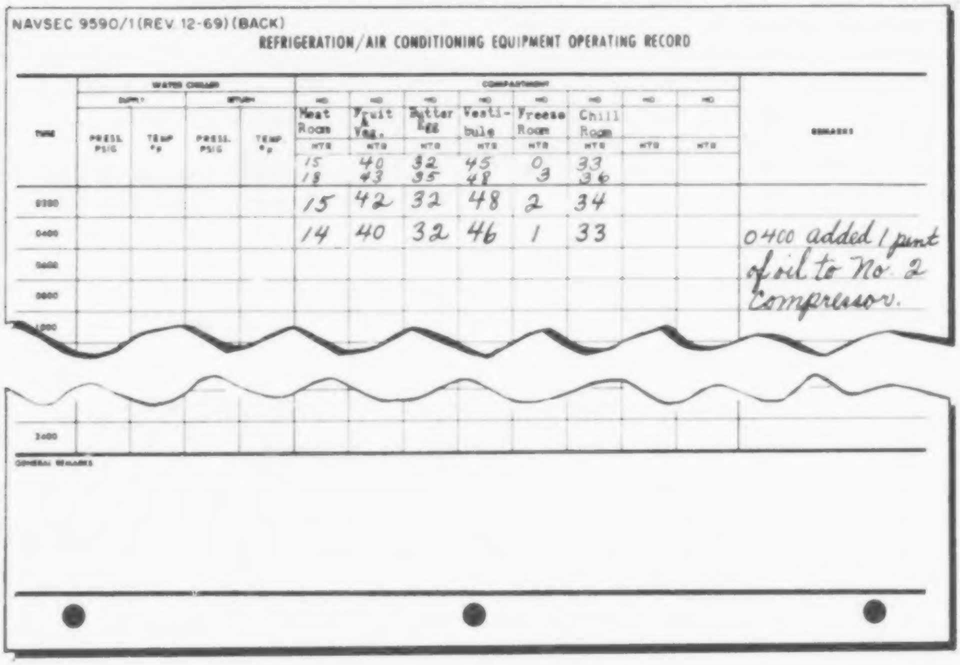
U.S.S. SAMPLE (CAG-132) DATE 5 SEPT 19

MAKE CARRIER	SIZE/MODEL 2 TONS 7H5	REFRIGERANT R-12	APPLICATION MAIN PLANT	PLANT NO 2	LOCATION 3-15-2-A

TIME	MACH. SPACE AMB. TEMP. °F	COMPRESSOR						CONDENSER (Water cooled)			LIQUID LINE			INITIALS
		SUCTION		DISCHARGE		LUBRICATING OIL		WATER SUPPLY		DISCH.	TEMP °F	CONDITION AT SIGHT FLOW INDICATOR	CONDITION AT MOISTURE INDICATOR	
		PRESS. PSIG	TEMP. °F	PRESS. PSIG	TEMP. °F	PRESS. PSIG	BULL'S-EYE LEVEL	PRESS. PSIG	TEMP. °F	TEMP. °F				
0200	89	13	18	98	152	48	N	35	78	82	80	C	D	J.E.B
0400	89	7	14	96	148	48	L	35	78	80	80	C	D	J.E.B.
0600														
0800														
2400														

(OVER)

A



NAVSEC 9590/1(REV 12-69)(BACK)

REFRIGERATION/AIR CONDITIONING EQUIPMENT OPERATING RECORD

TIME	WATER CHILLER				COMPARTMENT								REMARKS
	SUPPLY		RETURN		NO.	NO.	NO.	NO.	NO.	NO.	NO.	NO.	
	PRESS. PSIG	TEMP °F	PRESS. PSIG	TEMP °F	Meat Room	Fruit & Veg.	Butter Egg	Vesti-bule	Freeze Room	Chill Room			
					NTR	NTR	NTR	NTR	NTR	NTR	NTR	NTR	
					15 18	40 43	32 35	45 48	0 3	33 36			
0200					15	42	32	48	2	34			
0400					14	40	32	46	1	33			0400 added 1 pint of oil to No. 2 Compressor.
0600													
0800													
1000													
2400													

GENERAL REMARKS

B

47.104

Figure 10-40.—Refrigeration/Air-Conditioning Equipment Record, NAVSEC 9590/1. A. Front. B. Back.

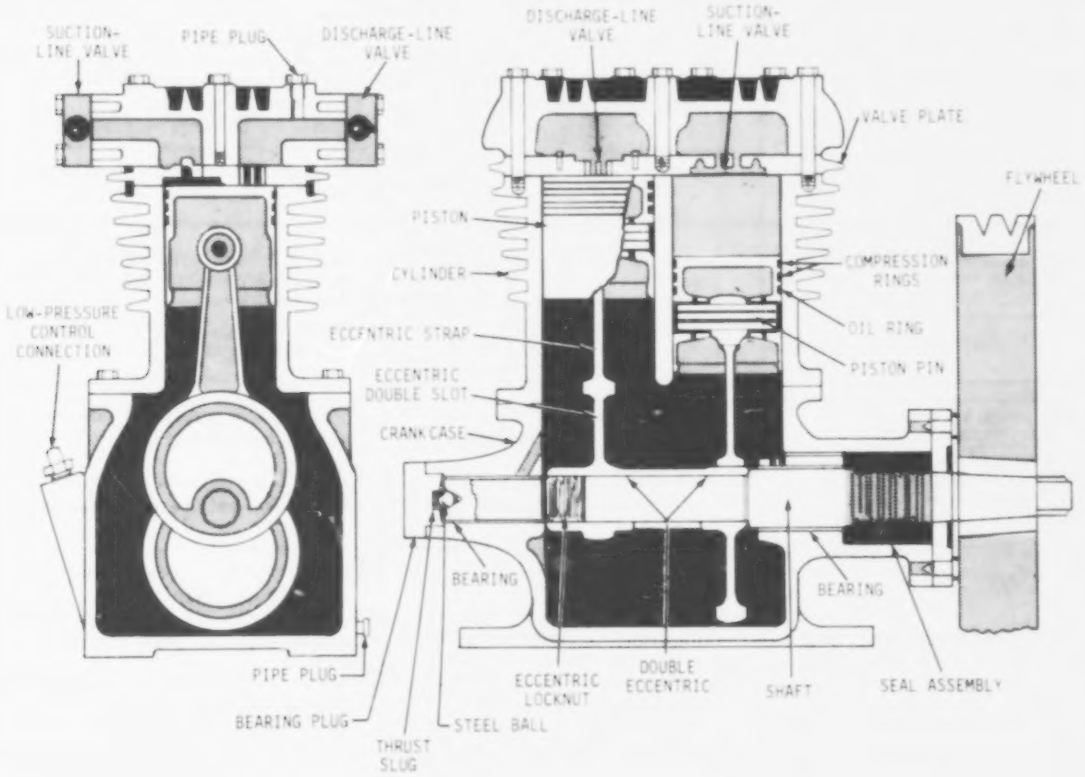
figure 10-40. The information recorded in this type of operating log may be used as a guide for a continuing analysis of the operating conditions and operating results found in a refrigeration or air-conditioning plants. The columns "Mach. space amb. temp. °F" and "water supply" are influencing conditions, a record which is desirable for comparative results. Other columns represent operating results. Where improper results are shown, an immediate check should be made to determine the cause and remedy. Such precautions may prevent serious problems. For example, when the actual suction temperature drops to the temperature corresponding to the existing suction pressure as indicated by the temperature and pressure scales on the suction pressure gauge, the return of liquid is definitely indicated. Further evidence of liquid slop-over will be shown by a drop in compressor discharge temperature. When liquid does return to the compressor, the trouble must be corrected at once to prevent damage to the compressor.

MAINTENANCE, SERVICING, AND REPAIR OF REFRIGERATING EQUIPMENT

As a Utilitiesman, you must be able to perform various duties in the maintenance, servicing and repair of refrigerating equipment. This phase of our discussion provides information on different jobs that you may be called upon to handle. When information here varies from that in the latest Federal or Military Specifications, the Specifications apply. You will find the "Troubleshooting Checklist—Refrigeration Systems," which is presented in table 10-4 in this chapter, a help in locating and correcting troubles. Manufacturers also provide instruction manuals that will aid you in maintaining and servicing their equipment.

MAINTENANCE OF OPEN TYPE OF COMPRESSORS

Closely observe figure 10-41 that shows a vertical single-acting reciprocating compressor. Some


SUCTION-LINE VALVE
PIPE PLUG
DISCHARGE-LINE VALVE
LOW-PRESSURE CONTROL CONNECTION
PIPE PLUG
BEARING PLUG
THRUST SLUG
STEEL BALL
DISCHARGE-LINE VALVE
SUCTION-LINE VALVE
VALVE PLATE
FLYWHEEL
PISTON
CYLINDER
ECCENTRIC STRAP
ECCENTRIC DOUBLE SLOT
CRANKCASE
COMPRESSION RINGS
OIL RING
PISTON PIN
BEARING
BEARING
ECCENTRIC LOCKNUT
DOUBLE ECCENTRIC
SHAFT
SEAL ASSEMBLY

54.291

Figure 10-41.—Vertical single-acting reciprocating compressor.

Table 10-4.—Troubleshooting Checklist—Refrigeration Systems

TROUBLE	POSSIBLE CAUSE	CORRECTIVE MEASURE
High condensing pressure.	Air or non-condensable gas in system.	Purge air from condenser.
	Inlet water warm.	Increase quantity of condensing water.
	Insufficient water flowing through condenser.	Increase quantity of water.
	Condenser tubes clogged or scaled.	Clean condenser water tubes.
	Too much liquid in receiver, condenser tubes submerged in liquid refrigerant.	Draw off liquid into service cylinder.
	Insufficient cooling of air-cooled condenser	Check fan operation, cleanliness of condenser, and for adequate source of air flow
Low condensing pressure.	Too much water flowing through condenser.	Reduce quantity of water.
	Water too cold.	Reduce quantity of water.
	Liquid refrigerant flooding back from evaporator.	Change expansion valve adjustment, examine fastening of thermal bulb.
	Leaky discharge valve.	Remove head, examine valves. Replace any found defective.
High suction pressure.	Overfeeding of expansion valve.	Regulate expansion valve, check bulb attachment.
	Leaky suction valve.	Remove head, examine valve and replace if worn.
Low suction pressure.	Restricted liquid line and expansion valve or suction screens.	Pump down, remove, examine and clean screens.
	Insufficient refrigerant in system.	Check for refrigerant storage.
	Too much oil circulating in system.	Check for too much oil in circulation. Remove oil.
	Improper adjustment of expansion valves.	Adjust valve to give more flow.
	Expansion valve power element dead or weak.	Replace expansion valve power element.

54.189

Table 10-4.—Troubleshooting Checklist—Refrigeration Systems—Continued

TROUBLE	POSSIBLE CAUSE	CORRECTIVE MEASURE
Compressor-short cycles on low-pressure control.	Low refrigerant charge.	Locate and repair leaks. Charge refrigerant.
	Thermal expansion valve not feeding properly. 1. Dirty strainers. 2. Moisture frozen in orifice or orifice plugged with dirt. 3. Power element dead or weak.	Adjust, repair or replace thermal expansion valve. 1. Clean strainers. 2. Remove moisture or dirt (Use system dehydrator). 3. Replace power element.
	Water flow through evaporators restricted or stopped. Evaporator coils plugged, dirty, or clogged with frost.	Remove restriction. Check water flow. Clean coils or tubes.
	Defective low-pressure control switch.	Repair or replace low-pressure control switch.
Compressor runs continuously.	Shortage of refrigerant.	Repair leak and recharge system.
	Leaking discharge valves.	Replace discharge valves.
Compressor short cycles on high-pressure control switch.	Insufficient water flowing through condenser, clogged condenser.	Determine if water has been turned off. Check for scaled or fouled condenser.
	Defective high-pressure control switch.	Repair or replace high pressure control switch.
Compressor will not run.	Seized compressor.	Repair or replace compressor.
	Cut-in point of low-pressure control switch too high.	Set L. P. control switch to cut-in at correct pressure.
	High-pressure control switch does not cut-in. 1. Defective switch. 2. Electric power cut off. 3. Service or disconnect switch open.	Check discharge pressure and reset H. P. control switch. 1. Repair or replace switch. 2. Check power supply. 3. Close switches.

54.189.1

Table 10-4.—Troubleshooting Checklist—Refrigeration Systems—Continued

TROUBLE	POSSIBLE CAUSE	CORRECTIVE MEASURE
Compressor will not run. (Cont'd)	4. Fuses blown.	4. Test fuses and renew if necessary.
	5. Overload relays tripped.	5. Re-set relays and find cause of overload.
	6. Low voltage.	6. Check voltage (should be within 10 percent of nameplate rating).
	7. Electrical motor in trouble.	7. Repair or replace motor.
	8. Trouble in starting switch or control circuit.	8. Close switch manually to test power supply. If OK check control circuit including temperature and pressure controls.
	9. Compressor motor stopped by oil pressure differential switch.	9. Check oil level in crankcase. Check oil pump pressure.
Sudden loss of oil from crankcase.	Liquid refrigerant slugging back to compressor crankcase.	Adjust or replace expansion valve.
Capacity reduction system fails to unload cylinders.	Hand-operating stem of capacity control valve not turned to automatic position.	Set hand-operating stem to automatic position.
Compressor continues to operate at full or partial load.	Pressure-regulating valve not opening.	Adjust or repair pressure-regulating valve.
Capacity reduction system fails to load cylinders.	Broken or leaking oil tube between pump and power element.	Repair leak.
Compressor continues to operate unloaded.	Pressure regulating valve not closing.	Adjust or repair pressure-regulating valve.

54.189.2

of the duties you may perform in maintaining open type of compressors are discussed below.

Shaft Bellows Seal

Refrigerant leakage often occurs at the shaft bellows seal, with consequent loss of charge. Install a test gauge in the line leading from the drum to the compressor. Attach a refrigerant drum to the suction end of the shutoff valve outlet port. Apply the proper amount of pressure, as recommended in the manufacturer's instructions. Test for leaks with a halide leak detector around the compressor shaft, seal gasket, and seal nut; slowly turn the shaft by hand. When a leak is located at the seal nut, replace the seal plate, gasket, and seal assembly; when the leak is at the gasket, replace the gasket only. Retest the seal after reassembly. (This procedure is typical for most shaft seals on reciprocating open type of compressors.)

Valve Obstructions

Obstructions, such as dirt or corrosion, may be formed under seats of suction or discharge valves. To locate the source of trouble, proceed as follows:

When the suction-side valve is obstructed, the unit tends to run continuously or over long periods. Connect the test gauge assembly and start the unit. The pressure gauge will not indicate an increase in pressure. The compound gauge will fluctuate and will not indicate any decrease in pressure. Clean out any obstructions and recheck again by using the test gauge assembly.

To determine whether there is a discharge valve leak, connect the test gauge assembly and start the unit. Run it until the low-side pressure gauge indicates normal pressure for the unit. Stop the unit. With an ear near the compressor housing, listen for a hissing sound. Also watch the gauges. When leakage caused by an obstruction is present, the low-side pressure rises, and the high side decreases until the pressures are equalized. A quick equalization of pressures indicates a bad leak that should be repaired immediately or the compressor replaced.

Compressor Lubrication

The oil level in the compressor crankcase should be checked by following the manufacturer's manual. Attach the gauge manifold to the suction and discharge valves. Pump the system down. Close the suction and discharge valves, isolating the compressor. Remove the oil filter plug and measure the oil level as per the manufacturer's manual.

Compressor Knocks

When a compressor knocks, you may have to disassemble the compressor to determine whether the cause of the knock is a loose connecting rod, piston pin, or crankshaft. Sometimes a loose piston pin can be detected without the complete disassembly. First, remove the cylinder head and valve plate to expose the top of the piston. Start the motor and press down with your finger on top of the piston. Any looseness can be felt at each stroke. The loose part should be replaced. Check the oil level first because knocks are often caused by oil levels that are too high. Always make sure that a low oil level is actually the result of a lack of oil rather than a low charge.

Stuck or Tight Compressor

A stuck or tight compressor often occurs as a result of poor reassembly after a breakdown repair. In such cases, determine where the binding occurs and reassemble the unit with correct tolerances; avoid uneven tightening of screws or seal covers.

INSPECTION

An inspection should be performed on the refrigeration unit from time to time for knocks, thumping, rattles, and so on, while the unit is in operation. When any of the external parts have excessive grease, dirt, or lint, they should also be cleaned. Before cleaning, be sure and shut the unit off for safety.

A careful check of the entire system with instruments or tools is essential to determine if there has been any loss of refrigerant. NO LEAK IS TOO SMALL TO BE FIXED. Each leak must be stopped immediately.

Some of the specific requirements for inspection of refrigeration systems are described below.

Inadequate lubrication of bearings and other moving parts is a continual source of trouble. This can usually be traced to a lack of maintenance resulting in low grease and oil levels or a poor condition of lubricating oil.

Rusty or corroded parts discovered during the inspection should be cleaned and painted.

Hissing sounds at the expansion valve, low readings on the discharge pressure gauge, and bubbles in the receiver sight glass, all indicate a weak refrigerant charge.

Loose connections and worn or pitted switch contacts result in inoperative equipment or reduced reliability. Thermostats with burned contacts may produce abnormal temperatures in the cooled compartment.

Fans difficult to rotate by hand, with bent blades, or loose or worn belts are a source of trouble easy to locate and correct during inspections.

Air filters clogged with dirt should be cleaned or replaced during the inspection.

Hermetically sealed units should be inspected for signs of leaks and high temperatures and for too much noise or vibration.

Open type of compressors should be checked for both oil and refrigerant leaks particularly at the shaft seal. Too, a compression test must be made to reveal the pressure of worn rings, defective suction valve, or faulty discharge valve.

Condenser assemblies require an adequate supply of coolant (air and water) properly directed. Inspection should be made for the proper positioning of baffles, general cleanliness, and proper fan operation.

Two sources of trouble with thermostatic expansion valves are the contact made by the equalizer and control bulbs. These areas must be inspected for loose contact, corrosion, and pinching of the connecting tubes.

Accessories, such as filter-dryer cartridges, oil traps, and strainers, must be checked. When clogged, they will prevent the normal flow of refrigerant.

The above list is not intended to be complete. The NAVFAC P-322 manual must be consulted for complete inspection instructions.

PRINCIPLES OF AIR CONDITIONING

Air conditioning is the process of conditioning the air in a space to maintain a predetermined temperature-humidity relationship to meet comfort or technical requirements. This cooling and warming of the air is usually referred to as winter and summer air conditioning. Winter and summer air conditioning is done by installing both cooling

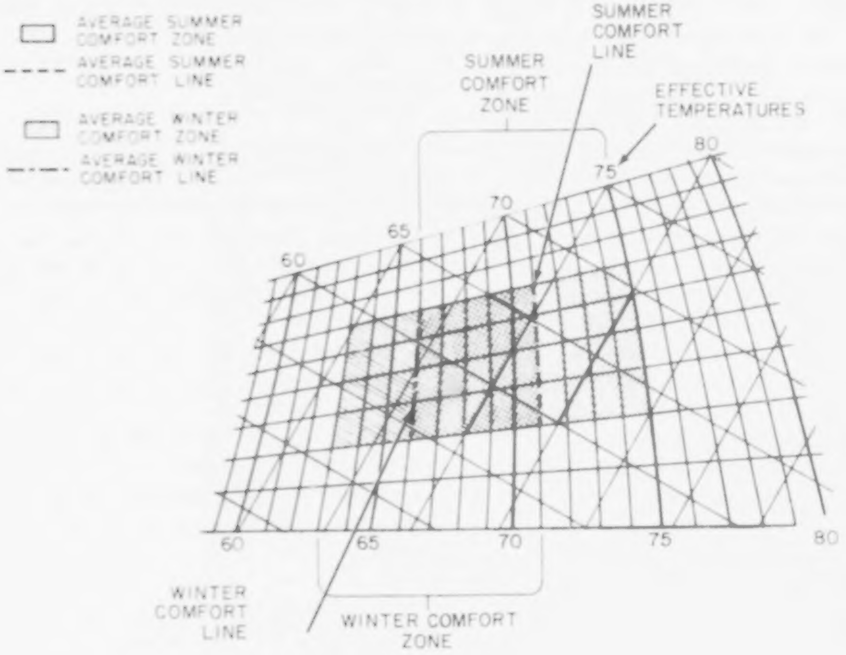


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Figure 10-42.—Comfort zones and lines.

and heating equipment in the air-conditioning system. Of course, single units for cooling or heating may be used separately.

Here, you are introduced to the operating principles of air-conditioning systems, the environmental factors controlled by air conditioning, and their effects on health and comfort. Refrigerative air-conditioners and general procedures pertaining to the installation, operation, and maintenance of these systems are examined. Also, the operation and maintenance of the controls used with these systems are explained. Some material in this chapter may repeat what has already been mentioned on refrigeration. Repetition of these principles should add to your learning experience.

The important factors in a complete air-conditioning system are temperature control, purity or cleanliness of air, and circulation of air. Complete air conditioning provides automatic control of these factors for both winter and summer outdoor weather.

A furnace only heats the air, a fan only moves the air, and a cooling coil only cools the air. A complete air-conditioning system should automatically cool or heat the air, increase or decrease the humidity, control the air movement, and clean the air.

TEMPERATURE

Three factors—temperature, humidity, and air motion—are interrelated in their effects on health and comfort. The term given to the net effects of these factors is *effective temperature*. This effective temperature cannot be measured with a single instrument; a psychrometric chart aids in calculating the effective temperature when given sufficient known conditions relating to air temperatures and velocity.

Research has shown that most persons are comfortable in air where the effective temperature lies within a narrow range. The range of effective temperatures within which most people feel comfortable is called the COMFORT ZONE. Since winter and summer weather conditions are markedly different, the summer zone varies from the winter zone. The specific effective temperature within the zone at which most people feel comfortable is called the COMFORT LINE (fig. 10-42).

HUMIDITY

Air at a high temperature and saturated with moisture makes us feel uncomfortable. However, with the same temperature and the air fairly dry, we may feel quite comfortable. Dry air, as it passes over the surface of the skin, evaporates the moisture sooner than damp air and consequently, produces a greater cooling effect. However, air may be so dry that it causes us discomfort. Air that is too dry causes the surface of the skin to become dry and irritates the membranes of the respiratory tract.

HUMIDITY is the amount of water vapor in a given volume of air. RELATIVE HUMIDITY is the amount of water vapor in a given amount of air in comparison with the amount of water vapor the air would hold at that temperature if it were saturated. Or, relative humidity may be remembered as a fraction or percentage of water vapor in the air; that is, DOES HOLD over CAN HOLD.

Relative humidity is determined by using a sling psychrometer. It consists of a wet-bulb thermometer and a dry-bulb thermometer, as shown in figure 10-43. The wet-bulb thermometer is an ordinary thermometer similar to the dry-bulb

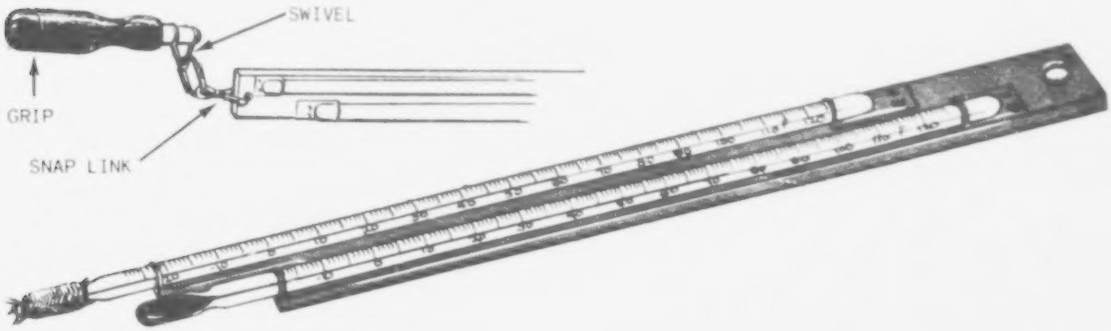

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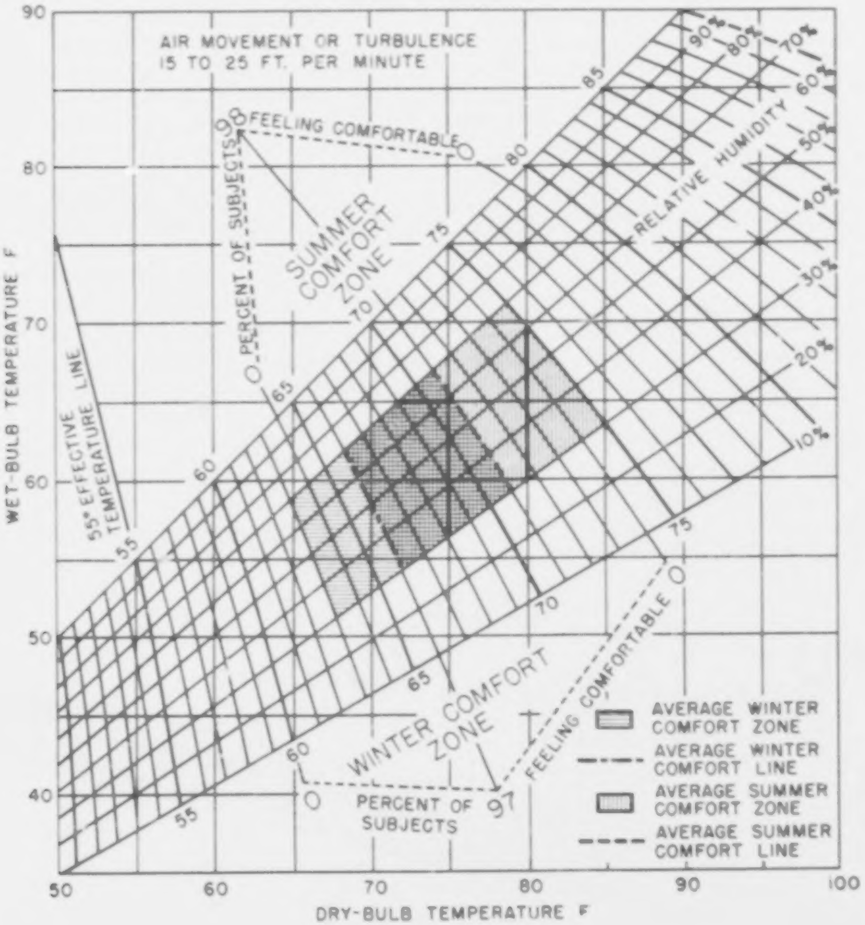
Figure 10-43.—A standard sling psychrometer.

thermometer, except that the bulb is enclosed in a wick that is wet with distilled water. The wet bulb is cooled as the moisture evaporates from it while it is being spun through the air. This causes the wet-bulb thermometer to register a lower temperature than the dry-bulb thermometer. Tables and charts have been designed that use these two temperatures to arrive at a relative humidity for certain conditions.

Figure 10-44 is called a comfort zone chart. The comfort zone is the range of effective temperatures over which the majority of adults feel comfortable. In looking over the chart, note that the comfort zone represents a considerable area. The chart shows the wet- and dry-bulb temperature combinations that are comfortable to the majority of adults. The summer comfort zone extends from 66 °F effective temperature to 75 °F effective temperature for 98 percent of all personnel. The winter comfort zone extends from 63 °F effective temperature to 71 °F effective temperature for 97 percent of all personnel.

Dew-Point Temperature

The dew point depends on the amount of water vapor in the air. If the air at a certain temperature is not saturated, that is, if it does not contain all the water vapor it can hold at that temperature, and the temperature of that air falls, a point is finally reached at which the air is saturated for the new and lower temperature, and condensation of the moisture begins. This is the



54.173

Figure 10-44.—Comfort zone chart.

dew-point temperature of the air for the quantity of water vapor present.

Relationship of Wet-Bulb, Dry-Bulb, and Dew-Point Temperatures

Definite relationships exist between the wet-bulb, dry-bulb, and dew-point temperatures. These relationships are as follows:

1. When the air contains some moisture but is not saturated, the dew-point temperature is lower than the dry-bulb temperature, and the wet-bulb temperature lies between them.
2. As the amount of moisture in the air increases, the amount of evaporation (and, therefore, cooling) decreases. The difference between the temperatures grows less.
3. When the air becomes saturated, all three temperatures are the same and the relative humidity is 100 percent.

To HUMIDIFY air is to increase its water vapor content. To DEHUMIDIFY air is to decrease its water vapor content. The device used to add moisture to the air is called a humidifier, and a dehumidifier is used to remove moisture from the air. The control device, sensitive to various degrees of humidity, is called a HUMIDISTAT.

Methods for humidifying air in air-conditioning units usually consist of an arrangement that causes air to pick up moisture. One arrangement may consist of a heated water surface over which conditioned air passes and picks up a certain amount of water vapor by evaporation, depending upon the degree of humidifying required.

Another arrangement to humidify air is to spray or wash the air as it passes through the air-conditioning unit.

During the heat of the day, the air usually absorbs moisture. As the air cools at night, it may reach the dew point and give up moisture which is deposited on objects. This principle is used in dehumidifying air by mechanical means.

Dehumidifying equipment for air conditioning usually consists of cooling coils within the air-conditioner. As warm, humid air passes over the cooling coils, its temperature drops below the dew point and some of its moisture condenses into water on the surface of the coils. The condensing moisture gives up latent heat, thereby creating a part of the cooling load that must be overcome by the air-conditioning unit. For this reason, the relative humidity of the air entering the conditioner has a definite bearing on the total cooling load. The amount of water vapor that can be removed from the air depends upon the air over the coils and the temperature of the coils.

PURITY OF AIR

The cleanliness of air is important for health. The air should be free from all foreign materials, such as ordinary dust, rust, animal and vegetable matter, pollen, carbon (soot) from poor combustion, fumes, smoke, and gases. Not only is foreign matter of these types harmful to the human body, but, in addition, the human body is endangered by the bacteria and harmful germs that are carried about by such foreign particles. So, the outside air brought into a space or the recirculating air within a space should be filtered during air conditioning.

The air in an air-conditioner may be purified or cleaned by filters, air washing, or electricity.

Filters may be designed as permanent or throwaway types. They are usually made of fibrous materials. The fibers collect the particles of dust and other foreign matter from the air as it passes through the filter. In some cases, the fibers are dry, while in others they have a viscous (sticky) coating. Filters normally have a large dust-holding capacity.

When filters become dust-laden, they must be either discarded or cleaned. Permanent filters are usually cleaned. The cleaning solution depends upon the composition of the filter. The manufacturer's recommendations and instructions should be followed. Throwaway filters are only one-time filters. When they become dust-laden, they must be discarded.

Often water sprays are used to recondition the air by washing and cleaning it. These sprays may also serve to humidify the air or dehumidify it to some extent. During the winter season, the water sprays will add a lot of moisture to the air if the water is warm. In the summer season, when the spray is kept cool, it tends to take moisture out of the air and make it drier. In this way, washing the air serves either to humidify or dehumidify, and to clean it—all in one operation.

In some large air-conditioning systems, air is cleaned by electricity. In this system, electrical precipitators remove the dust particles from the air. The air is first passed between plates where the dust particles are charged with electricity, then the air is passed through a second set of oppositely charged plates that attract and remove the dust particles (fig 10-45). This method is by far the best method of air cleaning, but the most expensive.

CIRCULATION OF AIR

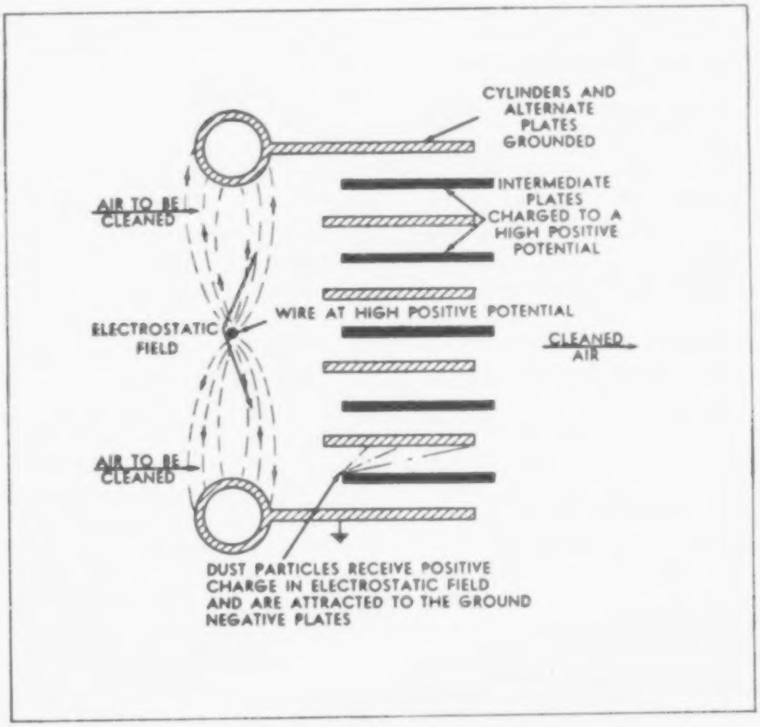
The circulation of air is important in air conditioning. The velocity of the air determines largely what temperature and humidity are required to produce comfort. (The chart in figure 10-44 is one of a set of charts and is based on an air movement of 15 to 25 feet per minute.) We know from experience that a high velocity of air produces a cooling effect on human beings. However, air velocity does not produce a cooling effect on a surface that does not have exposed moisture. A fan does not cool the air, but merely increases its velocity. The increased velocity of air passing over the skin surfaces evaporates the moisture at a greater rate, thereby cooling the individual. For this reason, circulation of air has a decided influence on comfort conditions. Air may be circulated by gravity or mechanical means.

When air is circulated by gravity, the cold, and therefore heavier, air tends to settle to the floor forcing the warm and lighter air to the ceiling. When the air at the ceiling has been cooled by some type of refrigeration, it will settle to the floor and cause the warm air to rise. The circulation of air in this type of system eventually stops when the temperature of the air at the ceiling and at the floor becomes the same.

Air may be circulated by mechanical means by axial or radial fans (squirrel cages) either mounted directly on electric motor shafts or mounted on a separate shaft and driven by pulleys and belts. When either the axial or radial fan is mounted in an enclosure, it is often called a blower.

HEATING AND COOLING EQUIPMENT

Heating equipment for air conditioning is usually automatic. Heating coils are usually built in the air-conditioning unit. These coils give up


CYLINDERS AND ALTERNATE PLATES GROUNDED
INTERMEDIATE PLATES CHARGED TO A HIGH POSITIVE POTENTIAL
AIR TO BE CLEANED
WIRE AT HIGH POSITIVE POTENTIAL
ELECTROSTATIC FIELD
CLEANED AIR
AIR TO BE CLEANED
DUST PARTICLES RECEIVE POSITIVE CHARGE IN ELECTROSTATIC FIELD AND ARE ATTRACTED TO THE GROUND NEGATIVE PLATES

54.372

Figure 10-45.—Diagram of an electrostatic filter.

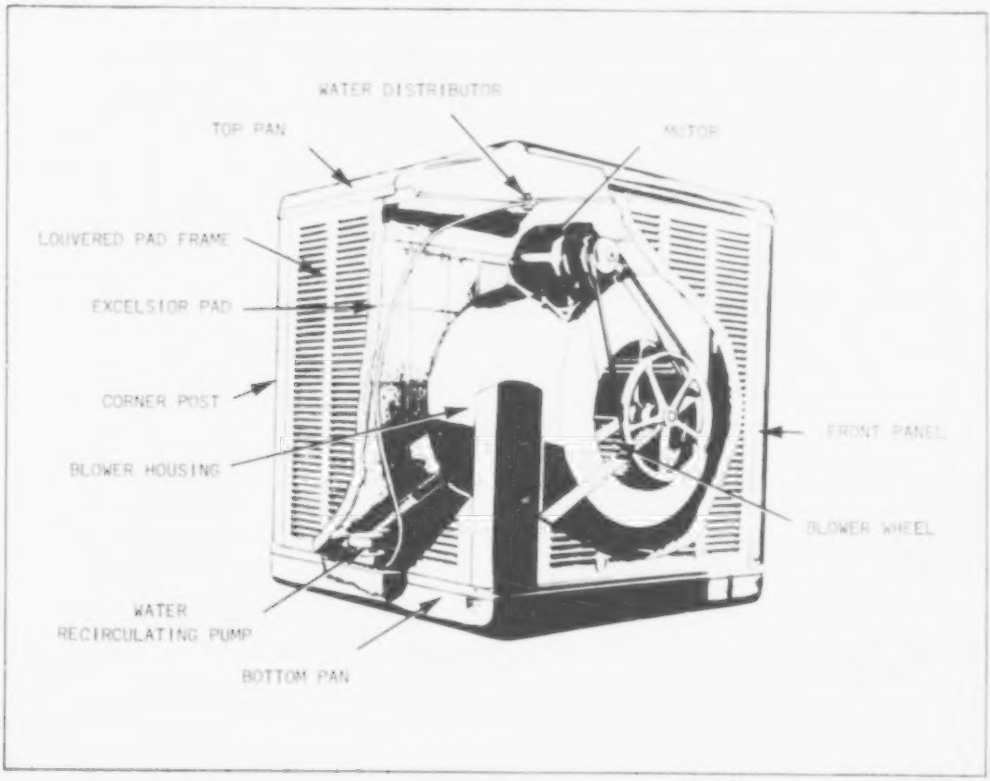
heat from the water or steam which passes through them from a heating unit. Heat may also be generated within an air-conditioning unit directly by a gas-heating unit or by an electrical heater. No matter what type of heat is used, the goal is to heat the air.

The cooling equipment for air conditioning must be of a type that will satisfactorily cool the air for a particular space that is being air-conditioned. One method used to cool air in air-conditioning units is to evaporate water. This method of cooling the air is referred to as evaporative cooling. Evaporative cooling of air is achieved by circulating air through a finely divided water spray or across a wet surface so that a portion of the water is evaporated continually. Latent heat of evaporation, which must be passed on to water to evaporate it, is supplied from the heat of incoming air, thereby reducing the dry-bulb temperature of the air. A cutaway view of the drip type of evaporative cooler is shown in figure 10-46.

One of the most important and positive methods to cool air in air-conditioning units is by mechanical refrigeration. A mechanical refrigeration system for air conditioning is designed with cooling coils that operate in a manner similar to that of an evaporator in a common refrigerator. These coils are usually cooled to about 50°F, and the air to be conditioned and cooled is blown through the coils. Cooling coils of this type also serve as dehumidifiers. When the humidity is high, some of the air that flows through the coils will be cooled below the dew point and will give up some of its moisture, causing the air to become dehumidified. This moisture collects on the cooling coils and is carried away by drains or evaporation.

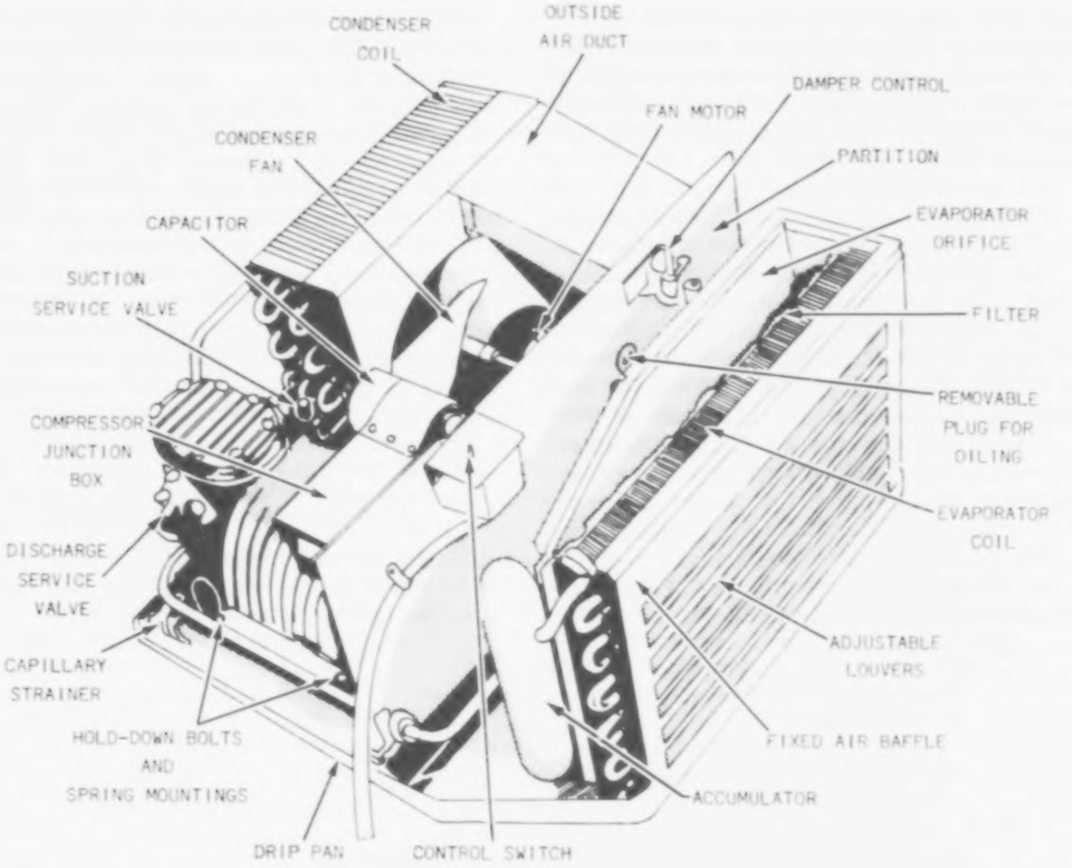
SELF-CONTAINED AIR-CONDITIONING UNITS

Self-contained refrigerative air-conditioning units may be divided into two groups: window- and floor-mounted units.



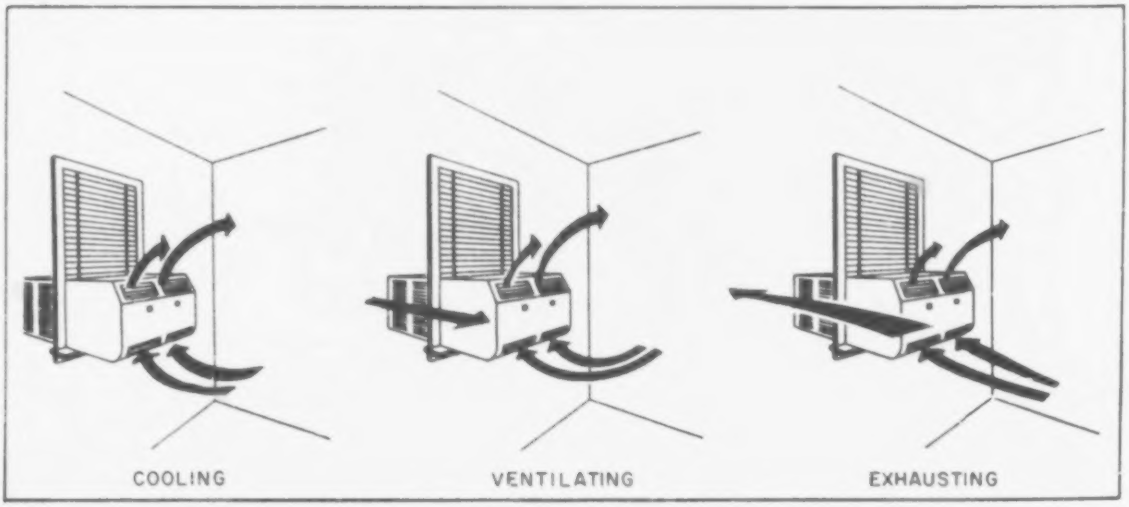
87.71

Figure 10-46.—Cutaway view of a drip type of evaporative cooler.


CONDENSER COIL
OUTSIDE AIR DUCT
DAMPER CONTROL
FAN MOTOR
CONDENSER FAN
PARTITION
CAPACITOR
EVAPORATOR ORIFICE
SUCTION SERVICE VALVE
FILTER
REMOVABLE PLUG FOR OILING
COMPRESSOR JUNCTION BOX
EVAPORATOR COIL
DISCHARGE SERVICE VALVE
ADJUSTABLE LOUVERS
CAPILLARY STRAINER
HOLD-DOWN BOLTS AND SPRING MOUNTINGS
FIXED AIR BAFFLE
ACCUMULATOR
DRIP PAN
CONTROL SWITCH

54.177

Figure 10-47.—Window air-conditioner.


COOLING
VENTILATING
EXHAUSTING

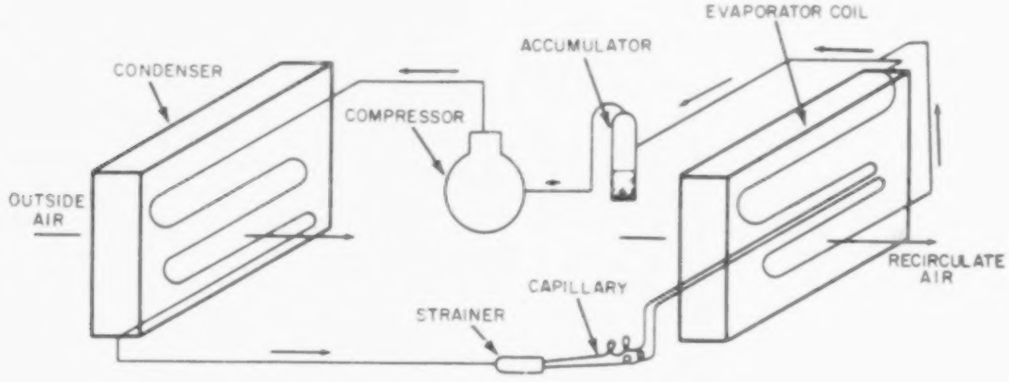
54.300

Figure 10-48.—Package type of room air-conditioner showing airflow patterns for cooling, ventilating, and exhausting services.

Window-mounted refrigerative air-conditioning units usually range from 4,000 to 36,000 Btu per hour in capacity. (See fig. 10-47.) The use of windows to install these units is not a necessity. They may be installed in transoms or directly in outside walls (commonly called a "through-the-wall" installation). The unit must have access to outside air for ventilation and exhaust and for the air-cooled condenser. A package type of room air-conditioner showing airflow patterns for cooling, ventilating, and exhausting services is shown in figure 10-48. It is a good idea to mount the unit on the east side of the building to take advantage of the afternoon shade.

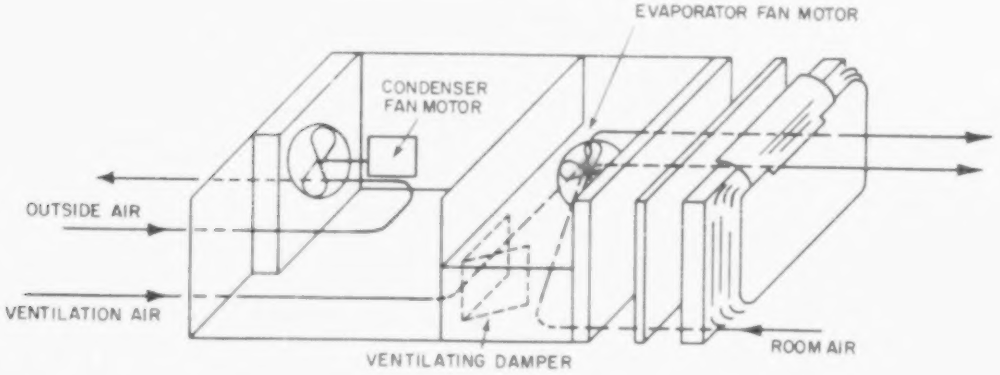
In construction and operating principles, the window unit is a small and simplified version of certain parts of a central system. As shown in figures 10-49 and 10-50, the basic refrigeration components are present in the window unit. The condenser coils are cooled by the air. The room air is circulated by a fan that blows across the evaporator coils. Moisture, condensed from the humid air by these coils, is collected in a pan at the bottom of the unit; it is usually drained to the back of the unit and discharged. Some condenser fans pick up the drainage in the form of droplets and mist and add them to the air blast that cools the condenser. Most window units are equipped with thermostats that maintain a fixed dry-bulb temperature and moisture content in an area within reasonable limits.

Floor-mounted refrigerative air-conditioning units range in size from 24,000 to 360,000 Btu per hour and are sometimes referred to as PACKAGE units. These larger units, like window units, contain the complete system of refrigeration components. A self-contained floor unit, with



54.301

Figure 10-49.—Refrigerant cycle of a package type of room air-conditioner.



54.302

Figure 10-50.—Air-handling components of a package type of room air-conditioner.

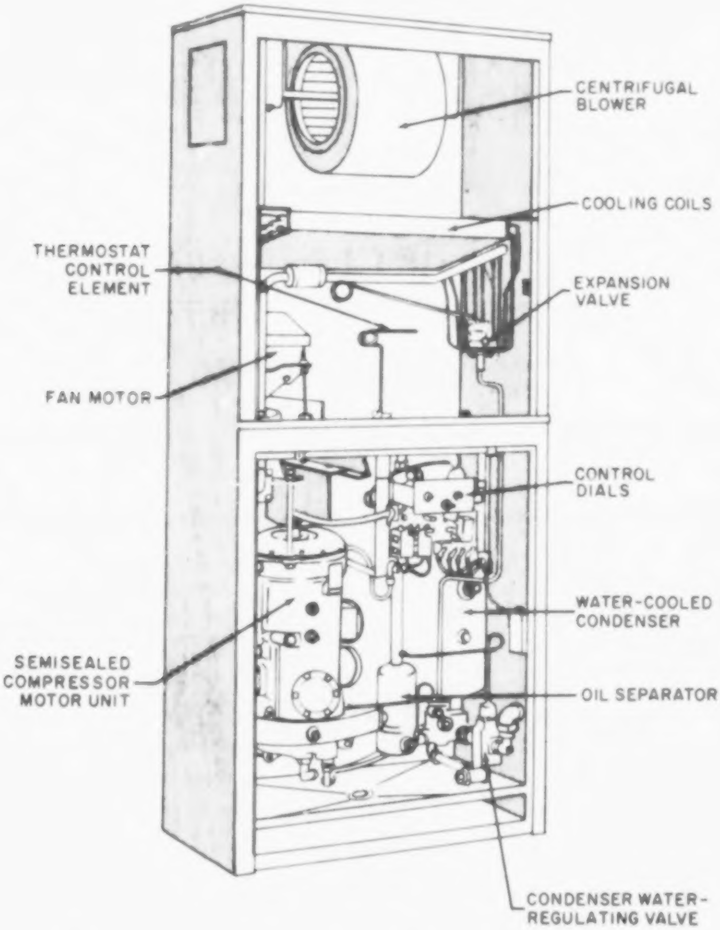
panels removed, is shown in figure 10-51. In the average installation of this type of equipment, either water-cooled or air-cooled condensers are used.

Window-mounted refrigerative air-conditioning units require very little mechanical attention before they are put into operation. The units are either sealed or of the semisealed type (hermetic). Hold-down bolts or wires may have to be removed or loosened before starting the unit for the first time.

Self-contained air-conditioning units or systems of all types are operated by users who should be properly instructed in their use.

Window units may be operated by the user as ventilating systems by operating the blower alone. Outside-air-intake dampers of these units are positioned for the most outside air circulation when used as ventilators. This operation is desirable during cooler seasons of the year when the introduction of outside air into the space results in satisfactory room conditions. When ventilation is not enough, the cooling or compressor control is set to the ON position. When the compressor is operated, outside-air-intake dampers are positioned to admit the least amount of outside air for maximum room cooling effect. Direction of airflow is regulated by the adjustable grille on the unit. Starting and stopping of both the blower and the compressor motors is usually automatically controlled by the thermostat.

Floor units may also be operated as a ventilating system by operating the blower only.


CENTRIFUGAL BLOWER
COOLING COILS
THERMOSTAT CONTROL ELEMENT
EXPANSION VALVE
FAN MOTOR
CONTROL DIALS
WATER-COOLED CONDENSER
SEMISEALED COMPRESSOR MOTOR UNIT
OIL SEPARATOR
CONDENSER WATER-REGULATING VALVE

54.178

Figure 10-51.—Floor-mounted air-conditioning unit.

The blower fan is started and stopped by manual operation of the fan switch. When blower operation is too low to cool, the compressor switch is turned to the ON position, and the compressor starts and stops by the action of the thermostat with changes in room temperature. Maximum refrigerated cooling is produced by systems using recirculated air when the outside air damper is set for introduction of a normal amount of outside air into the system during hot weather. When the system is designed for summer-winter operation, the changeover switch is set at either the summer or winter setting.

Refrigerating air-conditioning units are operated in the same manner as other refrigerating systems, except that they operate at higher temperatures and suction pressures. They should be checked regularly during the season when they are being operated to see that they work right. The filters should be renewed or cleaned weekly or more often if necessary. Always stop the blowers when changing the filters to keep loose dust from circulating through the system. Before disturbing the filters in hospitals, especially those serving operating rooms, always be sure that no operations are being or are about to be performed. The best time to clean these filters is in the afternoon after surgical work is completed. When the filters are permanent, they should be returned to the shop for cleaning.

At least once each year, the unit should be serviced to ensure that it is ready for the next season's operation. When the unit is designed with spray humidifier, spray nozzle, water strainers, and cooling coils, each device should be cleaned each month during the season to remove water solids and scale. Cooling coil casings, drain pans, fan scrolls, and fan wheels should be wire brushed and repainted when necessary. All fan and motor bearings should be checked for excessive wear and replaced when necessary. Oiling and greasing of the blower and motor bearings should be performed as required.

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Central Refrigeration Equipment for Air Conditioning, NFGS-15652, Department of the Navy, Naval Facilities Engineering Command, Alexandria, Va., 1987.

Introduction to Circuit Protection, Control, and Measurement, Navy Electricity and Electronics Training Series (NEETS), Module 3, NAVEDTRA 172-03-00-79, Naval Education and Training Program Management Support Activity, Pensacola, Fla., 1982.

APPENDIX I

GLOSSARY

ABSOLUTE ZERO—The point where all molecular motion ceases, $-460°F$.

AC—Alternating current.

ACCIDENT—Mishap.

AERATOR—Device for removing certain dissolved gases during water treatment.

AEROBIC DECOMPOSITION—Bacterial decomposition that occurs in the presence of oxygen.

AFTERCOOLER—Device which cools the final discharge from a compressor.

ANAEROBIC DECOMPOSITION—Bacterial decomposition occurring in the absence of free oxygen.

ASME—American Society of Mechanical Engineers.

BIB—Bibliography.

BOILER—An enclosed vessel that converts water to steam of proper temperature and pressure for an intended purpose.

BOILER SETTING—The structure that encloses a boiler and forms the furnace.

BOILING POINT—Temperature at which a liquid boils at a given pressure. For example, H_2O BP = 212°F or 100°C at sea level.

BREECHING—Connects a boiler to the stack.

BTU—British Thermal Unit.

CATHODIC PROTECTION—The use of material and liquid to cause electricity to flow to avoid corrosion.

CBMU—Construction Battalion Maintenance Unit.

CBU—Construction Battalion Unit.

CEC—Civil Engineer Corps.

CENTRIFUGAL FORCE—The force that impels a substance to move outward from the center of rotation.

CHLORINATION—Disinfection by chlorine chemical.

CISP—Cast-Iron Soil Pipe.

CLARIFICATION OF WATER—The removal of suspended materials to produce a clear, clean liquid.

CLEANOUT—A fitting installed in waste lines to allow removal of stoppages.

COMCBLANT—Commander Construction Battalions Atlantic.

COMCBPAC—Commander Construction Battalions Pacific.

CONDENSATION—The process of changing a vapor to a liquid.

CONDENSER—Component in a refrigeration system that removes and dissipates heat from a compressed refrigerant.

CONDUCTION—The transmitting of heat from one substance or part to another substance or part that are in direct contact with each other.

CONVECTION—The transfer of heat by means of mediums, such as water, air, and steam.

CSR—Central Storeroom.

CTR—Central Tool Room.

DC—Direct current.

DEGREE OF TEMPERATURE—Measurement of heat intensity.

DIATOMACEOUS EARTH—A porous mineral powder used as a filtering medium for the removal of suspended materials.

DISCHARGE HEAD—The pressure of a liquid as it leaves the discharge side of a pump.

DISINFECTION—Chemical destruction of bacteria.

EFFLUENT—Flowing out.

ESO—Educational Services Office.

EVAPORATOR—Component of a refrigeration system that permits the absorption of heat from a desired medium or space.

FILTRATION—The process of removing organisms, turbidity, iron, color, taste, and odor during the water treatment process.

FITTINGS—Devices which when placed in a pipe system make branch connections or changes in direction of a line.

FLASH POINT—The temperature at which a substance gives off enough vapor to support combustion (ignition temperature).

GALVANIZING—Treatment of wrought iron or steel that renders it corrosion resistant.

GENERAL RATING—Occupational fields of related duties and functions.

GPD—Gallons per day.

GPH—Gallons per hour.

GPM—Gallons per minute.

GROUNDWATER—Water absorbed by the earth's surface and collected below the waterline.

HEAD—The increase in pressure resulting from the addition of energy to a liquid by a pump.

HEAT—Energy that is measured in British thermal units.

HERMETICALLY SEALED—Caused to be airtight.

HOSE BIBB—Faucet installed where outside hose connections are needed.

HTH—High Test Calcium Hypochlorite.

HTHW—High-temperature hot-water system.

HUMIDITY—The amount of water vapor in a given volume of air.

HYDROLOGIC CYCLE—Process by which water is circulated from ocean to atmosphere to earth surface.

ID—Inside Diameter.

INFLUENT—Flowing in.

INTERCOOLER—Device that cools compressed gases between stages in a compressor.

JOINING—All procedures used to connect pipes together.

LATENT HEAT—Amount of heat required to change the state of a substance without a measurable change in temperature.

MAIN SOIL AND WASTE VENT—Portion of the waste stack that extends above the highest fixture branch.

MAPP—An all-purpose industrial fuel used with gas welding equipment; methyl-acetylene propadiene.

MECHANICAL PLANS—All layouts and details for systems of plumbing, heating, ventilating, air conditioning, and refrigeration.

MISHAP—Accident.

MLO—Material Liaison Officer.

MULTISTAGE PUMP—A pump having two or more devices for imparting a moving force upon a liquid.

NAVFAC—Naval Facilities Engineering Command.

NCR—Naval Construction Regiment.

NCTC—Naval Construction Training Center.

NEC—Navy Enlisted Classification Code.

NET POSITIVE SUCTION HEAD—Pump suction pressure minus vapor pressure expressed in feet of liquid at the pump suction.

NMCB—Naval Mobile Construction Battalion.

NPS--Nominal Pipe Size.

OCC STANDARDS—Occupational Standards.

OD—Outside Diameter.

P-TRAP—Type of fixture trap.

PACKING—Materials used to seal moving machinery joints against leakage.

PERMEABILITY—The capacity of stratum material to transmit water under pressure.

PHIBCB—Amphibious Construction Battalion.

PNEUMATIC—Moved or worked by air pressure.

POROSITY—The property of stratum material that contains openings through which water may flow.

POSTCHLORINATION—Disinfection following filtration.

POTABLE WATER—Water suitable for drinking, cooking, and personal use.

PRCP—Personnel Readiness Capability Program.

PRECHLORINATION—Disinfection before filtration.

PPM—Parts per million.

PSIG—Pounds per square inch gauge.

PRIME MOVER—A source of mechanical energy or power—the driving equipment.

PUMP—Mechanical device which applies a force to move any substance that flows or can be made to flow.

PUMP FLUID ENDS—Points where fluid enters or discharges from a pump.

PUMP POWER END—Point at which the prime mover drive system attaches to a pump.

R-12—Dichlorodifluoromethane (CCl_2F_2) refrigerant.

R-22—Monochlorodifluoromethane ($CHClF_2$) refrigerant.

R-717—Ammonia (NH_3) refrigerant.

RADIATION—The transfer of heat through space by heat waves.

RELATIVE HUMIDITY—The percentage of water vapor in the air when compared to the amount it does hold as to the amount it could hold.

REVERSE OSMOSIS—A process whereby a solution flows through a semipermeable membrane into an area of lower solute concentration.

ROICC—Resident officer in charge of construction.

ROUGHING IN—The installation of all parts of a plumbing system completed before installation of fixtures.

ROWPU—Reverse Osmosis Water Purification Unit. A mobile, lightweight unit capable of being air lifted to a deployment site.

SENSIBLE HEAT—Heat that can be measured in degrees of temperature with a thermometer.

SINGLE-STAGE PUMP—A pump having one device for imparting a moving force upon a liquid.

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SNAKING—Technique of laying pipe alongside or in a trench before final placement. This allows for thermal contraction or expansion of the pipe.

SPECIFIC HEAT—The quantity of heat expressed in Btu required to raise 1 pound of any substance 1°F in temperature.

SPECIFICATIONS—Statements that specify types and quality of materials and installation methods.

SUCTION HEAD—Total pressure of the liquid entering the pump.

SUPERHEAT—The amount of heat expressed in Btu added to a substance above its boiling temperature.

SURFACE WATER—Water in exposed streams, rivers, lakes, and ponds.

TOTAL DISCHARGE HEAD—The difference between a pump suction head and the discharge head.

TOTAL HEAT—Sensible heat plus latent heat expressed in Btu.

TRAP SEAL—Water held in the bend of a fixture trap.

TURBIDITY—Cloudiness in water caused by suspended solids.

UNLOADERS—System for removing all but friction loads from a compressor.

VAPORIZATION—The process of changing a liquid to a vapor.

VENT—A piping system that prevents siphonage of the trap seal by equalizing the pressure on the outlet side of a trap with the inlet side.

VISCOSITY—The ease or difficulty with which a liquid flows.

APPENDIX II

TABLES

MULTIPLY	BY	TO OBTAIN
Acres	43,560	square feet
Acres	4047	square meters
Acres	1.562×10^{-3}	square miles
Acres	5645.38	square yards
Acres	4840	square yards
Board-feet	0.2530	cubic inches
British thermal units	144 sq. in. × 1 in.	kilogram-calories
British thermal units	777.5	foot-pounds
British thermal units	3.927×10^{-4}	horsepower-hours
British thermal units	1054	joules
British thermal units	107.5	kilogram-meters
British thermal units	2.928×10^{-4}	kilowatt-hours
Btu per min	12.96	foot-pounds per sec
Btu per min	0.2356	horsepower
Btu per min	0.01757	kilowatts
Btu per min	17.57	watts
Btu per sq ft per min	0.1220	watts per square inch
Centiliters	0.01	liters
Centimeters	0.3937	inches
Centimeters	0.01	meters
Centimeters	393.7	mils
Centimeters	10	millimeters
Cubic centimeters	3.531×10^{-3}	cubic feet
Cubic centimeters	6.102×10^{-2}	cubic inches
Cubic centimeters	10^{-6}	Cubic meters
Cubic centimeters	1.306×10^{-6}	cubic yards
Cubic centimeters	2.642×10^{-4}	gallons
Cubic centimeters	10^{-3}	liters
Cubic centimeters	2.113×10^{-3}	pints (liq)
Cubic centimeters	1.057×10^{-3}	quarts (liq)
Cubic feet	2.832×10^{4}	cubic cms
Cubic feet	1728	cubic inches
Cubic feet	0.02832	cubic meters
Cubic feet	0.03704	cubic yards
Cubic feet	7.481	gallons
Cubic feet	28.32	liters
Cubic feet	59.84	pints (liq)
Cubic feet	29.92	quarts (liq)
Cubic feet per minute	472.0	cubic cms per sec
Cubic feet per minute	0.1247	gallons per sec
Cubic feet per minute	0.4720	liters per second
Cubic feet per minute	82.4	lbs of water per min
Cubic inches	16.39	cubic centimeters
Cubic inches	5.787×10^{-4}	cubic feet
Cubic inches	1.639×10^{-5}	cubic meters
Cubic inches	2.143×10^{-5}	cubic yards
Cubic inches	4.329×10^{-2}	gallons
Cubic inches	1.639×10^{-2}	liters
Cubic inches	0.03463	pints (liq)
Cubic inches	0.01732	quarts (liq)
Cubic meters	10^{6}	cubic centimeters
Cubic meters	35.31	cubic feet
Cubic meters	61.023	cubic inches
Cubic meters	1.303	cubic yards
Cubic meters	264.2	gallons
Cubic meters	10^{3}	liters
Cubic meters	2113	pints (liq)
Cubic meters	1057	quarts (liq)
Cubic yards	7.646×10^{5}	cubic centimeters
Cubic yards	27	cubic feet
Cubic yards	46.656	cubic inches
Cubic yards	0.7646	cubic meters
Cubic yards	202.0	gallons
Cubic yards	764.6	liters
Cubic yards	1616	pints (liq)
Cubic yards	807.9	quarts (liq)
Cubic yards per minute	0.45	cubic feet per second
Cubic yards per minute	3.367	gallons per second
Cubic yards per minute	12.74	liters per second
Days	24	hours
Days	1440	minutes
Days	86,400	seconds
Fathoms	6	feet
Feet	30.48	centimeters
Feet	12	inches
Feet	0.3048	meters
Feet	.36	yards
Feet	1/3	yards
Feet of water	0.02950	atmosphere
Feet of water	0.8826	inches of mercury
Feet of water	304.8	kgs per square meter
Feet of water	62.43	pounds per sq ft
Feet of water	0.4335	pounds per sq inch
Foot-pounds	1.286×10^{-3}	British thermal units
Foot-pounds	1.356×10^{7}	ergs
Foot-pounds	5.050×10^{-7}	horsepower-hours
Foot-pounds	1.356	joules
Foot-pounds	3.241×10^{-4}	kilogram-calories
Foot-pounds	0.1383	kilogram-meters

MULTIPLY	BY	TO OBTAIN	MULTIPLY	BY	TO OBTAIN
Foot-pounds	3.766×10^{-7}	kilowatt-hours	Kilometers	0.6214	miles
Gallons	3785	cubic centimeters	Kilometers	1093.6	yards
Gallons	0.1337	cubic feet	Kilowatts	56.92	Btu per min
Gallons	231	cubic inches	Kilowatts	4.425×10^{2}	foot-pounds per min
Gallons	3.785×10^{-3}	cubic meters	Kilowatts	737.6	foot-pounds per sec
Gallons	4.951×10^{-3}	cubic yards	Kilowatts	1.341	horsepower
Gallons	3.785	liters	Kilowatts	14.34	kg.-calories per min
Gallons	8	pints (liq)	Kilowatts	10^{3}	watts
Gallons	4	quarts (liq)	Liters	10^{2}	cubic centimeters
Horsepower	42.44	Btu per min	Liters	0.03531	cubic feet
Horsepower	33,000	foot-pounds per min	Liters	61.02	cubic inches
Horsepower	550	foot-pounds per sec	Liters	10^{3}	cubic meters
Horsepower	1.014	horsepower (metric)	Liters	1.308×10^{-2}	cubic yards
Horsepower	10.70	kg.-calories per min	Liters	0.2642	gallons
Horsepower	0.7457	kilowatts	Liters	2.113	pints (liq)
Horsepower	745.7	watts	Liters	1.057	quarts (liq)
Horsepower (boiler)	33.520	Btu per hour	Meters	100	centimeters
Horsepower (boiler)	9.804	kilowatts	Meters	3.2808	feet
Horsepower-hours	2547	British thermal units	Meters	39.37	inches
Horsepower-hours	1.98×10^{4}	foot-pounds	Meters	10^{-3}	kilometers
Horsepower-hours	2.684×10^{4}	joules	Meters	10^{3}	millimeters
Horsepower-hours	641.7	kilogram-calories	Meters	1.0936	yards
Horsepower-hours	2.737×10^{4}	kilogram-meters	Meter-kilograms	9.807×10^{7}	centimeter-dynes
Horsepower-hours	0.7457	kilowatt-hours	Miles	1.609×10^{3}	centimeters
Hours	60	minutes	Miles	5280	feet
Hours	3600	seconds	Miles	1.6093	kilometers
Inches	2.540	centimeters	Miles	1760	yards
Inches	10^{4}	mils	Miles	1900.8	yards
Inches	.03	yards	Ounces	8	drams
Inches of mercury	0.03342	atmospheres	Ounces	437.5	grains
Inches of mercury	1.133	feet of water	Ounces	28.35	grams
Inches of mercury	345.3	kgs per square meter	Ounces	0.0625	pounds
Inches of mercury	70.73	pounds per square ft	Ounces (fluid)	1.805	cubic inches
Inches of mercury	0.4912	pounds per square in	Ounces (fluid)	0.02957	liters
Inches of water	0.002458	atmospheres	Ounces (troy)	480	grains (troy)
Inches of water	0.07355	inches of mercury	Ounces (troy)	31.10	grams
Inches of water	25.40	kgs per square meter	Ounces (troy)	20	pennyweights troy
Inches of water	0.5781	ounces per square in	Ounces (troy)	0.08333	pounds (troy)
Inches of water	5.204	pounds per square ft	Ounces per sq inch	0.0625	pounds per sq inch
Inches of water	0.03613	pounds per square in	Pounds	7000	grains
Joules	9.486×10^{-4}	British thermal units	Pounds	453.6	grams
Kilograms	10^{3}	grams	Pounds	16	ounces
Kilograms	70.93	poundals	Pounds	32.17	poundals
Kilograms	2.2046	pounds	Pounds (troy)	0.8229	pounds (av)
Kilograms	1.102×10^{-3}	tons (short)	Pounds of water	0.01602	cubic feet
Kilometers	3281	feet	Pounds of water	27.68	cubic inches
Kilometers	10^{3}	meters	Pounds of water	0.1198	gallons

ENGLISH AND METRIC SYSTEM UNITS OF MEASUREMENT
COMMON EQUIVALENTS AND CONVERSIONS

Approximate Common Equivalents		Conversions Accurate to Parts Per Million (units stated in abbreviated form)	
		Number X Factor	
1 inch	= 25 millimeters	in X 25.4*	= mm
1 foot	= 0.3 meter	ft X 0.3048*	= m
1 yard	= 0.9 meter	yd X 0.9144*	= m
1 mile†	= 1.6 kilometers	mi X 1.60934	= km
1 square inch	= 6.5 square centimeters	in^2 X 6.4516*	= cm^2
1 square foot	= 0.09 square meter	ft^2 X 0.0929030	= m^2
1 square yard	= 0.8 square meter	yd^2 X 0.836127	= m^2
1 acre	= 0.4 hectare	acres X 0.404686	= ha
1 cubic inch	= 16 cubic centimeters	in^3 X 16.3871	= cm^3
1 cubic foot	= 0.03 cubic meter	ft^3 X 0.0283168	= m^3
1 cubic yard	= 0.8 cubic meter	yd^3 X 0.764555	= m^3
1 quart (lq.)	= 1 liter	qt (lq.) X 0.946353	= *l*
1 gallon	= 0.004 cubic meter	gal X 0.00378541	= m^3
1 ounce (avdp)	= 28 grams	oz (avdp) X 28.3495	= g
1 pound (avdp)	= 0.45 kilogram	lb (avdp) X 0.453592	= kg
1 horsepower	= 0.75 kilowatt	hp X 0.745700	= kW
1 pound per square inch	= 0.07 kilogram per square centimeter	psi X 0.0703224	= kg/cm^2
1 millimeter	= 0.04 inch	mm X 0.0393701	= in
1 meter	= 3.3 feet	m X 3.28084	= ft
1 meter	= 1.1 yards	m X 1.09361	= yd
1 kilometer	= 0.6 mile	km X 0.621371	= mi
1 square centimeter	= 0.16 square inch	cm^2 X 0.155000	= in^2
1 square meter	= 11 square feet	m^2 X 10.7639	= ft^2
1 square meter	= 1.2 square yards	m^2 X 1.19599	= yd^2
1 hectare	= 2.5 acres	ha X 2.47105	= acres
1 cubic centimeter	= 0.06 cubic inch	cm^3 X 0.0610237	= in^3
1 cubic meter	= 35 cubic feet	m^3 X 35.3147	= ft^3
1 cubic meter	= 1.3 cubic yards	m^3 X 1.30795	= yd^3
1 liter	= 1 quart (lq.)	*l* X 1.05669	= qt (lq.)
1 cubic meter	= 250 gallons	m^3 X 264.172	= gal
1 gram	= 0.035 ounces (avdp)	g X 0.0352740	= oz (avdp)
1 kilogram	= 2.2 pounds (avdp)	kg X 2.20462	= lb (avdp)
1 kilowatt	= 1.3 horsepower	kW X 1.34102	= hp
1 kilogram per square centimeter	= 14.2 pounds per square inch	kg/cm^2 X 14.223226	= psi

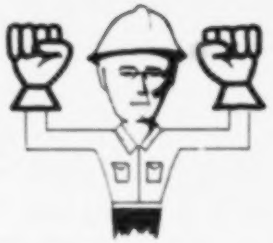
†nautical mile = 1.852 kilometers

* exact

APPENDIX III

HAND SIGNALS

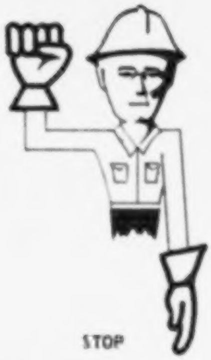
GENERAL



EMERGENCY STOP

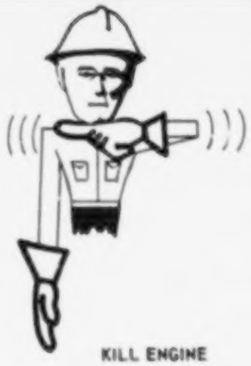
(STOP ALL MOTION AS QUICKLY AS POSSIBLE.)

1



STOP

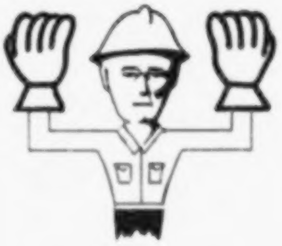
2



KILL ENGINE

(SECURE ENGINE AS PRESCRIBED.)

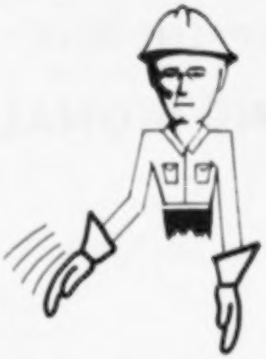
3



MANEUVER FORWARD SLOW AND EASY

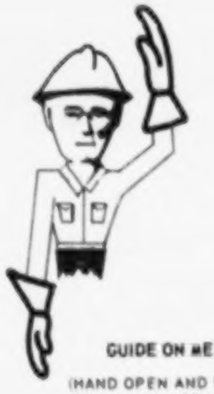
(WHEN MANEUVERING IN CLOSE QUARTERS OR TO MOVE A FOOT OR TWO AT A TIME.)

4



SLOW DOWN

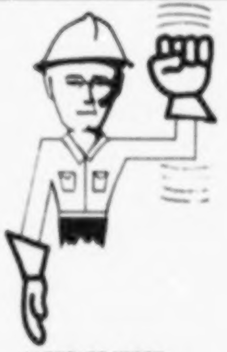
5



GUIDE ON ME

(HAND OPEN AND PALM FACING INWARD.)

6

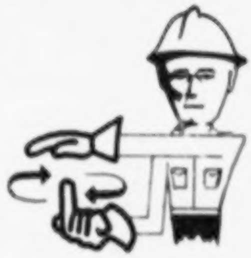


INCREASE SPEED

(HURRY UP AND MOVE OUT, DOUBLE TIME, ETC.)

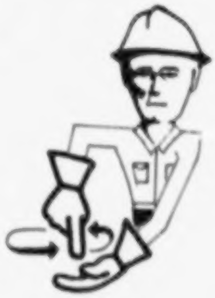
7

HOISTING & DERRICK SIGNALS



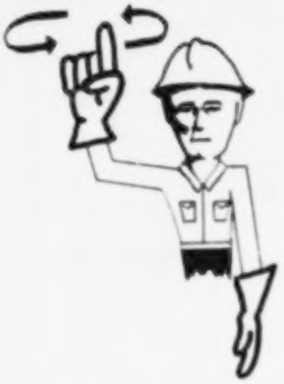
RAISE OR HOIST SLOWLY

8

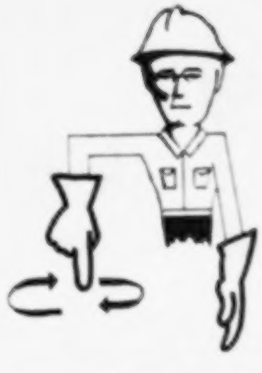


LOWER SLOWLY

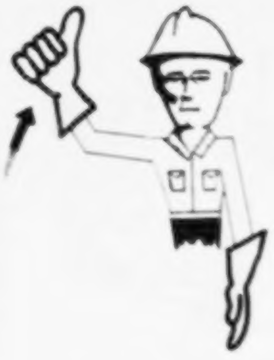
9



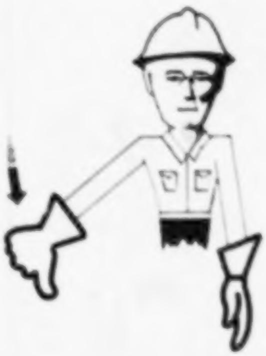
10 RAISE THE LOAD



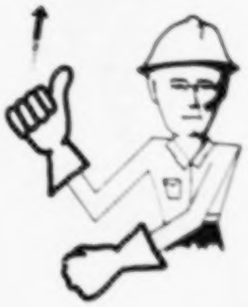
11 LOWER THE LOAD



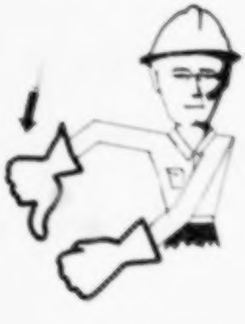
12 RAISE THE BOOM



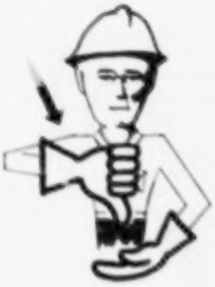
13 LOWER THE BOOM



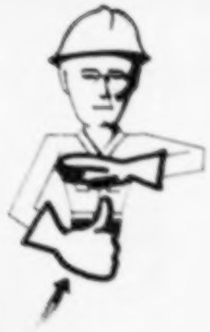
14 RAISE THE BOOM AND HOLD THE LOAD



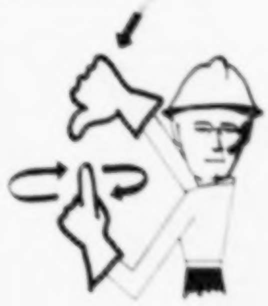
15 LOWER THE BOOM AND HOLD THE LOAD



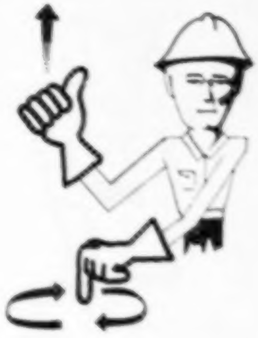
16 LOWER THE BOOM SLOWLY



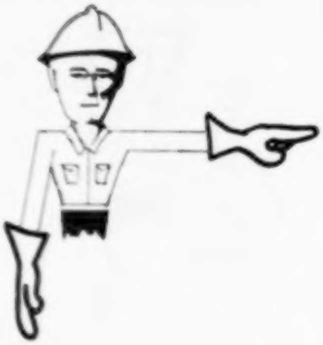
17 RAISE THE BOOM SLOWLY



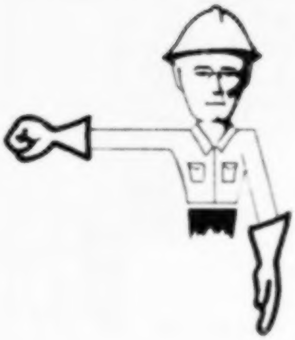
18 LOWER THE BOOM AND RAISE THE LOAD



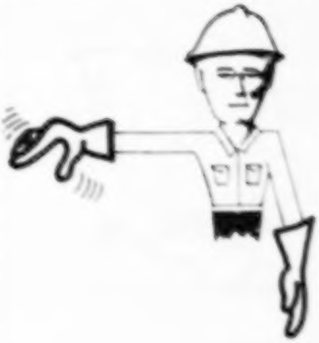
19 RAISE THE BOOM AND LOWER THE LOAD



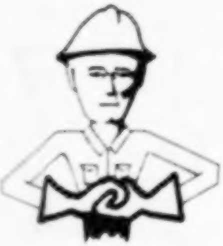
20 SWING IN DIRECTION FINGER POINTS



21 CLOSE BUCKET

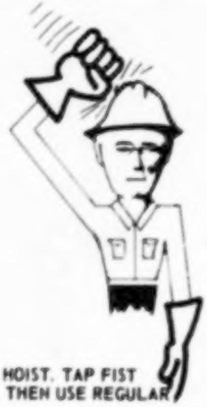


22 OPEN BUCKET



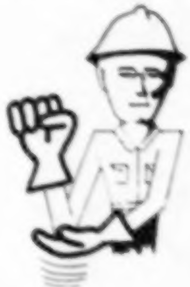
23 DOG EVERYTHING

(LOCK ALL BRAKES. DO NOT MOVE UNTIL FURTHER INSTRUCTIONS ARE GIVEN.)



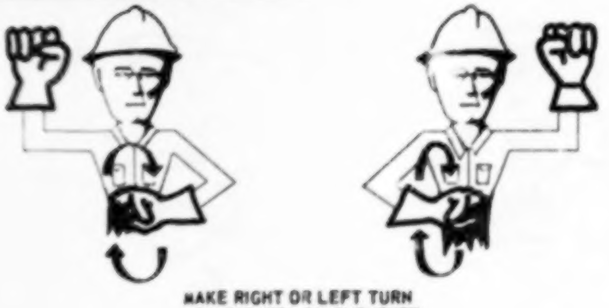
24 USE MAIN HOIST. TAP FIST ON HEAD, THEN USE REGULAR SIGNALS.

CRAWLER EQUIP. - INCLUDES CRANES



25 USE WHIP LINE.

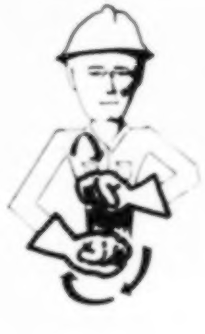
(AUXILIARY HOIST) TAP ELBOW WITH ONE HAND, THEN USE REGULAR SIGNALS.



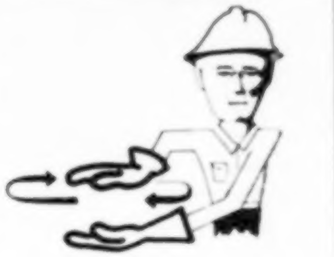
26 MAKE RIGHT OR LEFT TURN AS INDICATED BY CLENCHED FIST.

LEFT

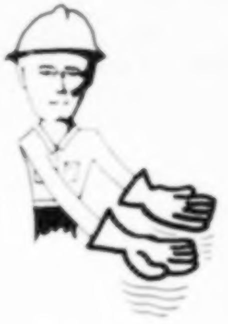
RIGHT



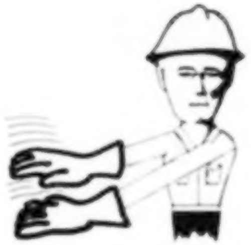
27 TRAVEL BOTH TRACKS



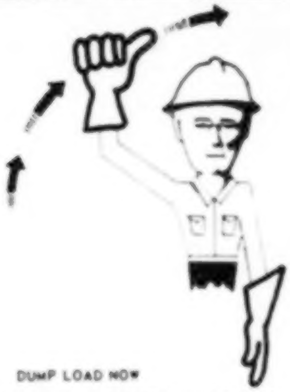
WHEN CUT, FILL OR HAUL ROAD IS TO BE DRAGGED OR BLADED, POINT TO THE AREA, THEN RUB PALMS OF HANDS TOGETHER INDICATING A SMOOTHING MOTION. APPLIES TO SCRAPERS, MOTOR GRADERS AND BULLDOZERS. 28



29 RAISE A LITTLE

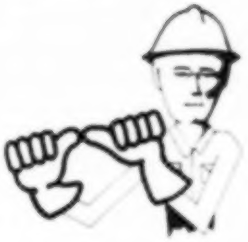


30 LOWER A LITTLE

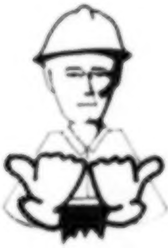


31 DUMP LOAD NOW

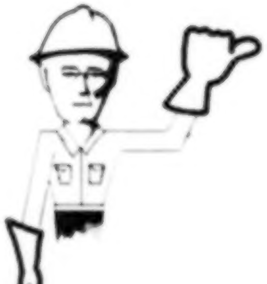
(START DUMPING AND SPREADING LOAD TO PROPER DEPTH IF GIVEN.)



32 REHAUL OR RETRACT

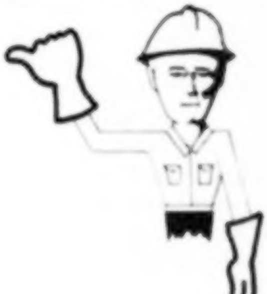


33 CROWD OR EXTEND



34

TURN RIGHT (TO THE OPERATOR'S RIGHT.)



35

TURN LEFT (TO THE OPERATOR'S LEFT.)

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